DOCUMENT RESUME

ED 210 065 JC 810 635

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TITLE Biology Modules for the Visually Handicapped.
SPONS AGENCY California Community Colleges, Sacramento. Office of the Chancellor.
PUB DATE [81]
NOTE 87p.: Project supported by the California Community Colleges Fund for Instructional Improvement. Photographs may not reproduce well.

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Biology; *Multisensory Learning; Science Instruction; *Science Materials; Teacher Developed Materials; *Three Dimensional Aids; Two Year Colleges; Two Year College Students; *Visual Impairments

ABSTRACT

The instructional materials presented and described in this document were prepared as part of a project to develop enrichment materials for visually impaired biology students. A wide range of biology topics are presented, including most subjects covered in a one-semester course for nonmajors. Typewritten handouts, duplicating the content of Braille and audio cassette materials which were also developed during the project, are presented along with descriptions and photographs of 20 three-dimensional models, which were developed to help students understand the biological processes and concepts presented in the handouts. After an introduction to the project, the handouts define terms and present information in brief enumerated statements related to the following topics: (1) basic chemistry; (2) carbohydrates; (3) lipids; (4) protein; (5) enzymes; (6) cells; (7) bioenergetics; (8) cellular respiration; (9) deoxyribonucleic acid (DNA); (10) DNA and protein synthesis; (11) cell division; (12) basic inheritance; (13) evolution; (14) ecology; (15) population and ecosystem dynamics; (16) nature observation; and (17) plant biology. Student use of the three-dimensional models is discussed in the appropriate sections. Special instructions for nature observation and a chapparal field trip stress the sounds, smells, and textures of nature. Finally, the descriptions and photographs of the models are presented. (AYC)

BIOLOGY MODULES FOR THE VISUALLY HANDICAPPED

BY

DOUGLAS M. ALLAN

ACKNOWLEDGEMENTS

This project was supported by the California Community College fund for instructional improvement, under the direction of the State Chancellor's office. The written sections on carbohydrates and proteins are based on handouts developed originally by Jim Kerr and Chuck Schneebeck. Models were constructed by Paula Mckenzie Allan, Mary Allan, and Doug Allan. Ali Mesghali built the levels of chromosome structure model. The protein synthesis model is based on a design developed by Mark Hoffmann. Judy Daniels provided technical support and typed the manuscript. Material was brailled by the staff of the Sixth District PTA, San Jose, California, and by Joyce Robinowitz. Braille materials were reproduced at the Braille Institute, Los Angeles, California. Chris Schinenberger, Cathy Molini, Judy Schwartz, Maxine Hagins, and Art Marshburn provided valuable assistance during this project.

INTRODUCTION

Biology is often taught in such a visual way that learning barriers exist for the non-sighted student. Such barriers cannot be eliminated completely, but it does seem appropriate to attempt to modify learning situations as much as possible to accomodate the visually handicapped students. This project has involved the production of enrichment materials for the non-sighted general biology student.

I initially encountered a blind student during my first year of teaching. He quickly caused me to realize that my standard teaching techniques were not especially suitable for him. Subsequently the student and I discussed methods that might be used to increase his understanding of biological concepts. I developed a six week course, "Biology for the Blind", which involved an attempt to teach biological concepts in somewhat novel ways. Recently, I attended an AAAS short ~~course~~ on "Handicapped Students in Science". The course made me realize that special segregated courses are less appropriate than a "mainstreaming" approach. I decided that it would be valuable to develop materials for blind students that could be used in mainstream situations.

During the 1979-1980 school year I created a series of learning modules designed to aid blind biology students. Each module consists of several components including a typewritten handout, a Braille version of the handout, a cassette tape version of the handout, and models to accompany several of the handouts. The entire package of modules covers a wide range of topics, including most subjects covered in a typical one semester non-majors course. Each module is capable of standing by itself as a study aid in a particular subject area.

It is important to emphasize that readily available materials can often be used to enhance the learning experience for blind students. For example, pipe cleaners can represent chromosomes, modeling clay can be quickly fashioned into structures representing cellular organelles, and flow charts can be arranged with Braille words on bulletin boards. The instructor should always attempt to be imaginative in developing simple materials for blind students.

One of the goals of this project was to develop several permanent models. Many three dimensional models are available from commercial sources, but these often lack sufficient relief and detail. I attempted to build models for concepts that are not available from commercial sources.

BASIC CHEMISTRY

I. Atomic Structure

A. Basic Units of the Atom

1. Electron: A small negatively charged particle found in the atom. Electrons are in orbits around the nucleus of the atom.

2. Proton: A relatively large positively charged particle found in the nucleus of the atom.

3. Neutron: A relatively large neutral particle found in the nucleus of an atom.

B. The atomic number is the number of protons in an atom. The atomic number for a specific element never varies.

C. The atomic weight of an atom depends on its number of protons and neutrons.

1. Each proton weighs one atomic weight unit. Each neutron weighs one atomic weight unit. Each electron weighs so little that it is not considered when determining the weight of the atom.

2. Determine the atomic weight for each of the following atoms.

Name of the Atom	# of Protons	# of Neutrons	Atomic Weight in Atomic Weight Units
Hydrogen	1	0	
Oxygen	8	8	
Nitrogen	7	8	
Carbon	6	6	

D. Each kind of atom may occur as a number of different isotopes. All isotopes of an element have the same number of protons, but differ from each other in the number of neutrons.

E. A simple set of rules enables you to diagram the structure of an atom if you know its atomic number.

1. In a neutral atom the number of electrons is the same as the atomic number.

2. The first energy level never holds more than two electrons, and must be full with two electrons before additional electrons before additional electrons will be added to the second energy level.

3. The second energy level never holds more than eight electrons, and must be full with eight electrons before additional electrons will be added to the third energy level.

4. The third energy level will accept eight electrons before electrons are added to the fourth energy level.

5. Use the above rules to diagram the structures of the following atoms:

A. Hydrogen #1
B. Oxygen #8
C. Nitrogen #7
D. Carbon #6

II. Interactions of Atoms

A. Stability of atoms depends on the number of electrons in the outermost energy level.

1. An atom with one energy level is stable when it has two electrons.

2. An atom with two energy levels is stable when the second energy level contains eight electrons.

3. An atom with three energy levels is stable when the third energy level contains eight electrons.

B. Atoms tend to become stable by gaining, losing, or sharing electrons.

1. An atom which loses an electron to become stable becomes a positively charged ion.

2. An atom which gains an electron to become stable becomes a negatively charged ion.

3. A positive ion and a negative ion, due to opposite charges, may form a linkage called an ionic bond.

4. Some atoms share electrons with other atoms in order to become stable. Neither atom gains nor loses an electron. The linkage which results from the sharing of electrons is called a covalent bond.

C. Covalent bonds play major roles in the structure of biological molecules.

1. 95% of living matter is composed of atoms of only four different elements covalently bonded into molecules. The four important elements are hydrogen, oxygen, nitrogen, and carbon.

2. The number of bonds that will be formed by the four elements are the following:

   Hydrogen - 1 bond
   Oxygen - 2 bonds
   Nitrogen - 3 bonds
   Carbon - 4 bonds

   This group of elements and their bonding needs may be remembered by the mnemonic device "HONC" (honk of the horn for example).

3. The following are some examples of how the four important elements may be covalently bonded to make molecules:

   A. Water H - O - H

   B. Carbon Dioxide O = C = O

   C. Methane

```
    H
    |
H - C - H
    |
    H
```

   D. Ammonia

```
H
|
N - H
|
H
```

III. Construction of Molecules

Your instructor will demonstrate how to build molecules with ball and stick models. These should help you to understand the structure of molecules.

MOLECULES OF LIFE: CARBOHYDRATES

1. Carbohydrates are fundamental compounds in living organisms. They store energy and serve as fuel for the work of the cell. They are also used as building materials of the organism.

2. Carbohydrates can be divided into three groups, monosaccharides, disaccharides and polysaccharides.

3. Monosaccharides are the simple sugars. They are represented by the type formula $(CH_2O)n$ where n can be any number from 3 to 7.

4. Examples of monosaccharides:

   $C_3H_6O_3$---triose sugar---glyceraldehyde

   $C_5H_{10}O_5$--pentose sugars--ribose, deoxyribose

   $C_6H_{12}O_6$--hexose sugars--glucose, fructose, galactose

5. Disaccharides are compounds composed of two monosaccharides (simple sugars). The disaccharides important to biology have the molecular formula $C_{12}H_{22}O_{11}$.

6. These three disaccharides are the important ones.

   $C_{12}H_{22}O_{11}$--sucrose is a molecule composed of (glucose and fructose) joined together.

   --lactose is a molecule composed of (glucose and galactose) joined together.

   --maltose is a molecule composed of (glucose and glucose) joined together.

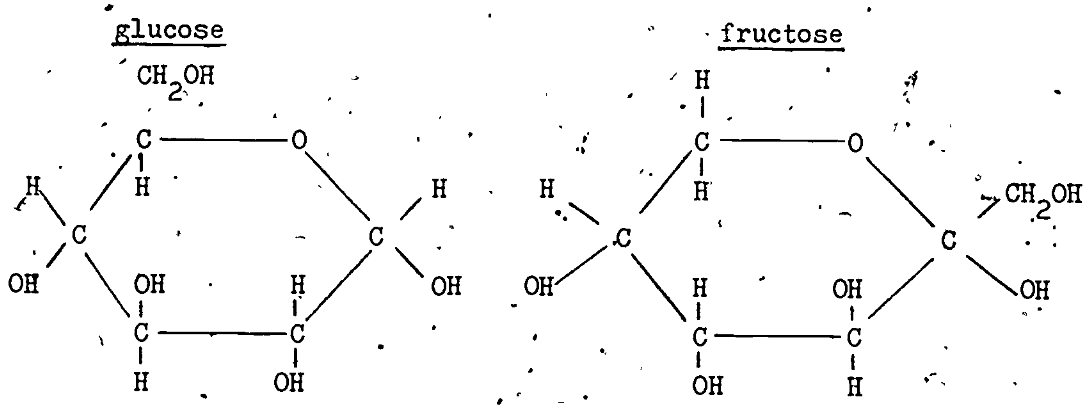
7. Polysaccharides are compounds composed of many sugar units. The type formula for the common polysaccharides is $(C_6H_{10}O_5)n$.

8. Examples of some common polysaccharides:

   Starches
   Glycogen — Made up of many glucose molecules.
   Cellulose

9. Many carbohydrates share a molecular formula with one or more other carbohydrates. They differ from each other in their structural formulas. They are ISOMERS.

10. Glucose and fructose are isomers. They both have the molecular formula $C_6H_{12}O_6$, but they have different structural formulas.



11. The chemical characteristics of glucose and fructose are different as a result of their different structural formulas.

12. Glucose

    Occurs commonly in fruits and vegetables. Component of all common disaccharides. Constituent of many polysaccharides. THE physiological sugar.

    Fructose

    Found in free form in many fruits. Constituent of sucrose. Very sweet sugar. Sweeter than glucose or sucrose.

13. Carbohydrates differ from each other in two primary respects, their solubility in water and their molecular size. Both characteristics are important to living organisms.

14. In order for molecules to be transported in the blood or to pass through cell membranes they must be dissolved in water.

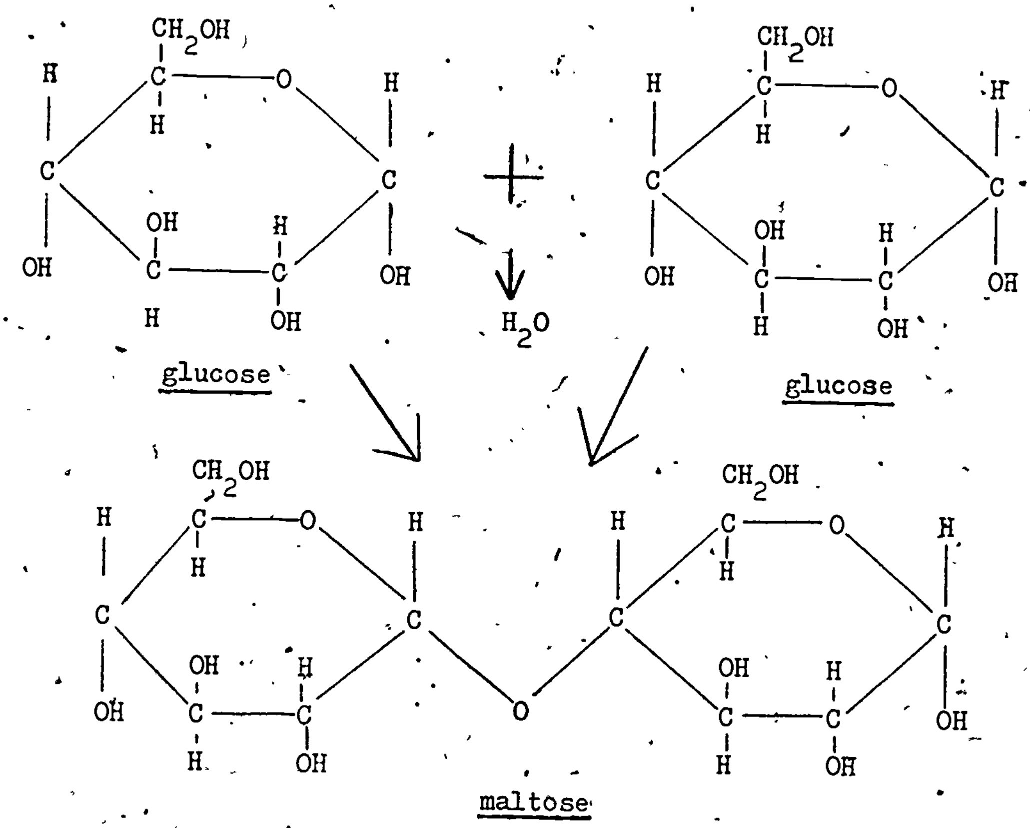
15. Solubility characteristics of some common carbohydrates in water:

Soluble	Insoluble
Glucose	Amylopectin--a form of starch
Fructose	Cellulose
Galactose	Glycogen
Amylose--a form of starch	
Sucrose	
Lactose	

16. Large molecules cannot permeate cell membranes even if they are soluble in water. In order to be absorbed from the gut, disaccharides and polysaccharides must be digested into soluble monosaccharides.

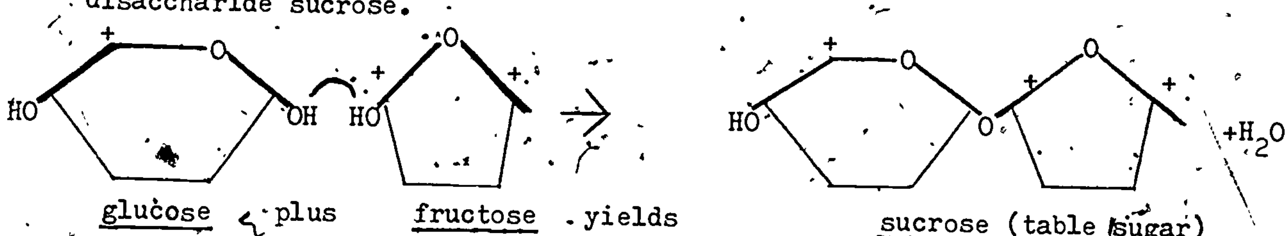
17. Monosaccharides are the building blocks of the disaccharides and polysaccharides. Each monosaccharide incorporated into a larger molecule is called a MONOMER.

18. Two glucose molecules bond together to form one maltose molecule.



19. The bonding together of the two glucose molecules with the concurrent removal of one molecule of water is an example of DEHYDRATION SYNTHESIS. The bond formed between two carbohydrate molecules during dehydration synthesis is called a GLUCOSIDE BOND.

20. Glucose and fructose combine through dehydration synthesis to form the disaccharide sucrose.

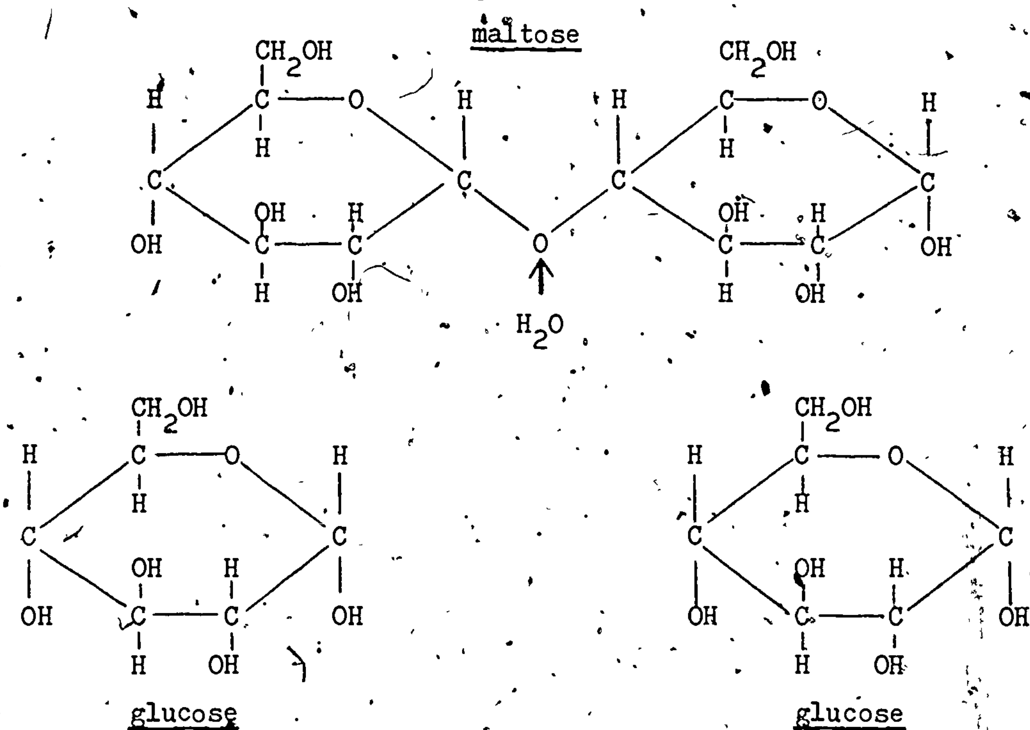


21. Glucose is the carbohydrate used as a fuel by most organisms. The oxidation of glucose is represented by the following equation.

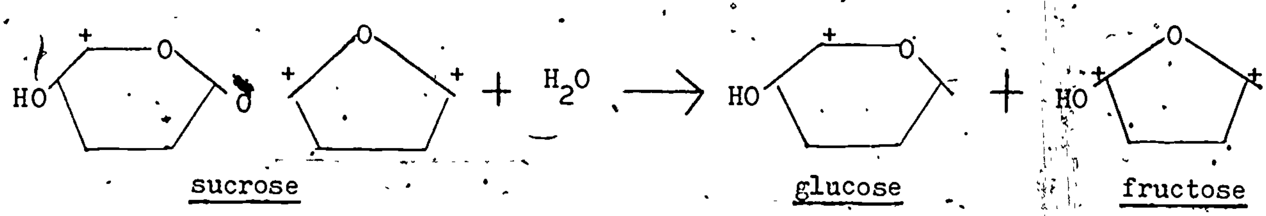
$C_6H_{12}O_6$	+ $6O_2$	$\longrightarrow$	$6CO_2$	+ $6H_2O$	+ energy
glucose	oxygen		carbon dioxide	water	(4Kcal/g glucose)

22. Disaccharides and polysaccharides included in the diet are digested into monosaccharides. Digestion happens by HYDROLYSIS. A molecule of water is added, breaks a glucoside bond, and releases a monosaccharide.

23. Maltose is hydrolized to two glucose molecules.



24. Sucrose is hydrolized to a glucose and a fructose molecule.



LIPIDS

1. Lipids are an important group of organic compounds in living organisms. Some of their functions are to store energy, provide insulation, act as a shock absorbing material, and as structural components of cell membranes.

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2. All lipids contain C, H, and O. The ratio of hydrogen to oxygen is always greater than 2:1 (as found in carbohydrates). Some lipids contain P and often N.

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3. Lipids include two classes of compounds:
   1. Fats. Nonpolar molecules which are important in food storage.
   2. Complex lipids. Polar molecules which have important structural roles in cell membranes.

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4. A fat molecule is constructed from two kinds of molecules.
   1. An alcohol. Usually glycerol.

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ & & H & & \end{array}$$

   2. Fatty acids. There are many kinds of fatty acids which differ from each other in molecular size. Some common fatty acids are listed below.

Formula	Fatty Acid Name	Commonly found in
C_3H_7COOH	Butyric	Butter
$C_{15}H_{31}COOH$	Palmitic	Animal and Vegetable Fats
$C_{17}H_{35}COOH$	Stearic	Animal and Vegetable Fats
$C_{25}H_{51}COOH$	Cerotic	Beeswax, wool fat, etc.

Each fatty acid has a carboxyl group $-\overset{\displaystyle O}{\overset{\|}{C}}-O-H$ attached to a group of carbon and hydrogen atoms. The general formula for a fatty acid is written $R-\overset{\displaystyle O}{\overset{\|}{C}}-O-H$, where R is a variable number of carbon and hydrogen atoms.

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5. The R portion of a fatty acid molecule is composed only of hydrogen and carbon atoms. It is known as the hydrocarbon end of the fatty acid molecule.

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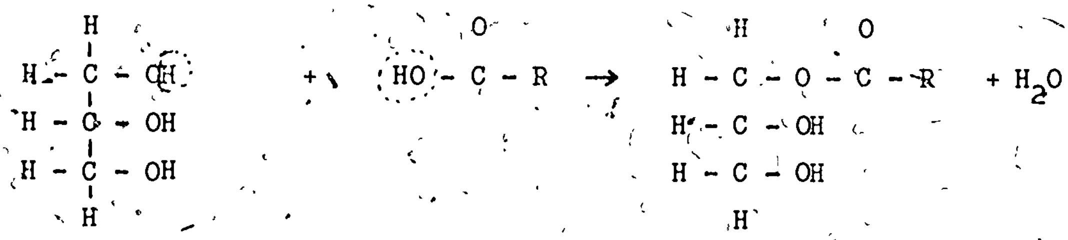
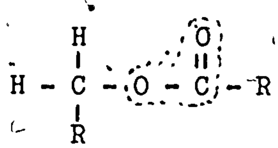
6. A fat molecule is formed when three fatty acid molecules attach to a glycerol molecule. A H^+ is removed from the glycerol molecule and an OH^- is removed from the fatty acid molecule. These ions join to form a molecule of water.



glycerol fatty acid

The linkage formed between the glycerol molecule and the fatty acid molecule is called the ester group.



ester group

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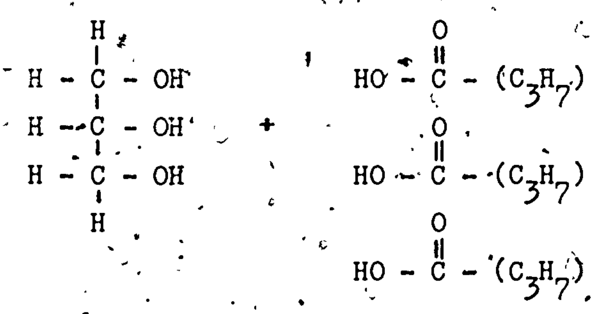
7. The following equation illustrates the synthesis of the fat commonly found in butter:



glycerol fatty acids

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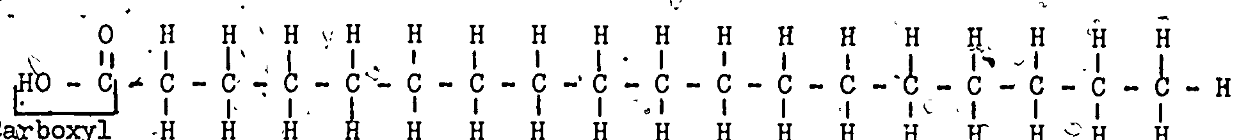
8. Fatty acids occur in two forms, saturated and unsaturated fatty acids. Saturated fatty acids have all single bonds in the hydrocarbon end of the fatty acid molecule. Unsaturated fatty acids have one or more double bonds between C atoms in the hydrocarbon end of the fatty acid molecule.

Saturated fatty acid

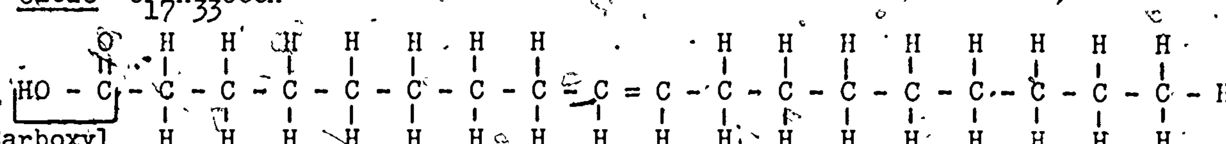
Stearic $C_{17}H_{35}COOH$



Carboxyl group

Singly unsaturated fatty acid

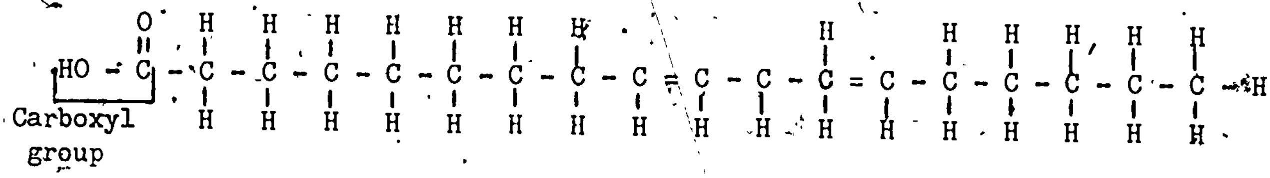
Oleic $C_{17}H_{33}COOH$



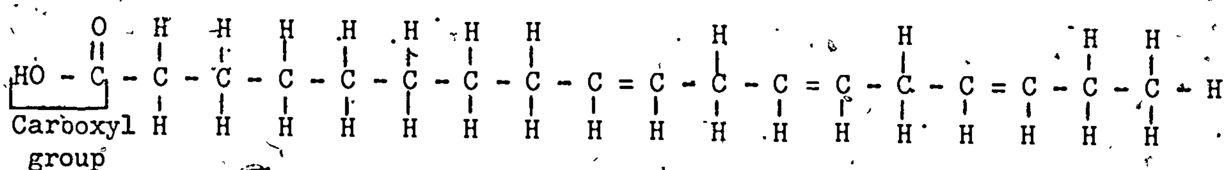
Carboxyl group

Doubly and triply unsaturated fatty acids (polyunsaturated)

Linoleic $C_{17}H_{31}COOH$



Linolenic $C_{17}H_{29}COOH$



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9. The degree of unsaturation of the fatty acids determines the melting point of a fat. The more unsaturated the fatty acids, the lower the melting point of the fat. Fats which have melted are called oils.

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10. Complex lipids are important structural components of cell membranes. Complex lipids are the second class of lipids.

A phosphate group is always part of a complex lipid. For this reason, complex lipids are often called phospholipids.

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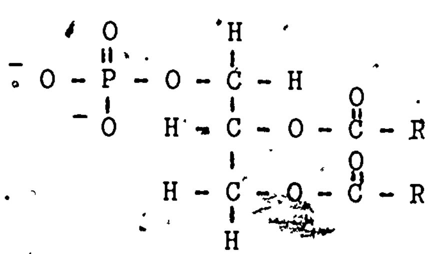
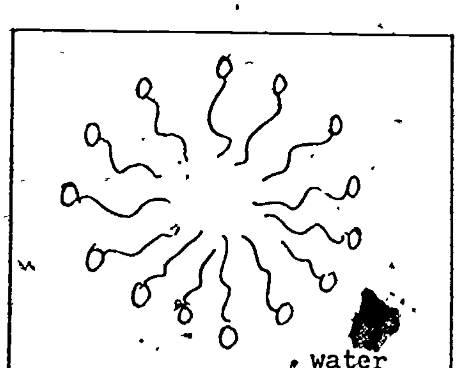
11. Complex lipids (phospholipids)

Each complex lipid has a glycerol molecule with two fatty acids and a phosphate group attached.



Phosphate has a negative charge on an oxygen atom and choline, for example, has a positive charge at the N atom. The result is polarity at one end of the molecule. The fatty acid end of the molecule has no polarity and does not mix with water. The polar end of the molecule mixes well polar water molecules.

- charged portion of molecule
- hydrophobic portion of molecule (has no charge)



MOLECULES OF LIFE: PROTEINS

1. Living things are made of thousands of different molecules which perform a fantastic variety of jobs in the body. As biologists try to understand these "molecules of life" it is necessary to group them into classes according to their similarities and differences. All of the proteins belong to one such class. Carbohydrates make up another. Lipids make up still another.

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2. The body of an average animal or human is composed of 60% water, 20% protein, 14% lipids, and about 1% carbohydrates. The remainder is minerals and nucleic acids.

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3. Here is a list of animal and plant materials in which proteins are the principle components: hair, fur, feathers, scales, skin, leather, fingernails, hooves, cartilage, muscles, embryo or germ portion of seeds.

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4. Here are some familiar foods which are important for their protein content.

milk	5% protein	cashews	18% protein	
cheese	25% "	soybeans	40% "	
eggs	12% "	wheat germ	25% "	
hamburger	25% "	sunflower seeds	25% "	

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5. Some proteins are especially important because of the jobs they perform in life processes. In this category are the enzymes.

   Enzymes serve as catalysts mediating the many biochemical processes occurring within cells and in the digestive system. For example, the digestion of starch is mediated by an enzyme named amalase.

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6. Other proteins serve as antibodies.

   Antibodies are produced by the blood system and protect against infections and diseases. Under some conditions antibodies cause problems. For example, antibodies are involved in allergies, Rh incompatibility, and rejection of transplanted organs.

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7. Still some other proteins serve as hormones (but many hormones are not proteins.)

   Hormones are "chemical messengers". They are synthesized in one part of the body and are transported to other parts where they exert their effects. Insulin is a hormone which is a protein. It is synthesized and secreted by the islet cells of the pancreas and stimulates the liver and muscles to remove glucose from the blood.

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8. Protein molecules are composed of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S).

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9. Protein molecules are relatively big and complicated. For this reason, they are sometimes called macromolecules.

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10. Protein molecules are composed of simpler and smaller molecules called amino acids which are joined together into chains or polymers.

The connecting links joining the amino acids are called peptide bonds. For this reason proteins are sometimes called polypeptides.

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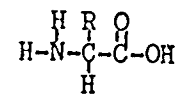
11. Here is the generalized structure of amino acid molecules. They are all alike to this extent.



"R" does not stand for an atom. It stands for a side chain (or radical) whose structure need not be shown in the generalized version.

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12. The central carbon atom in the amino acid molecule is called the alpha carbon.

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13. $-\overset{\overset{O}{\|}}{C}-OH$ is called a carboxyl group. Often it is shown like this: -COOH.

When placed in water carboxyl groups liberate hydrogen ions (H+) which are also called protons. Thus carboxyl groups are acidic. The carboxyl group is sometimes referred to as the acid group.

$$-COOH \longrightarrow -COO^- \text{ and } H^+$$

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14. $-\overset{\overset{H}{|}}{N}-H$ is called an amino group. Often it is shown like this: $-NH_2$.

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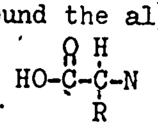
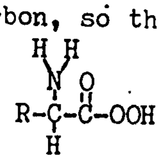
15. Amino acids can be shown in a variety of ways. One form is shown in frame 11, but there is no particular sequence by which the groups are arranged around the alpha carbon, so the following structures are equally valid:





etc.

The main thing to remember about the structure is that an amino group, a carboxyl group, a hydrogen atom, and a side chain (R) are all attached to the alpha carbon.

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16. There are 20 or perhaps a few more different amino acids that participate in the structure of proteins; thus there are that many different side chains. The total is not quite definite because the authorities disagree on whether or not several should be included. For example cystine is

two molecules of cystiene joined together. Some authors count both cystine and cystiene; others only cystiene.

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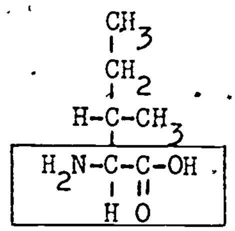
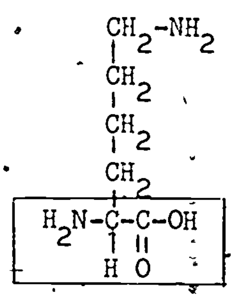
17. Eight of the twenty amino acids are considered essential to human nutrition. These eight amino acids must be eaten because they are not manufactured in the body.

The eight essential amino acids and their "R" groups are listed below:

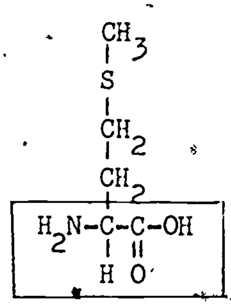
Isoleucine



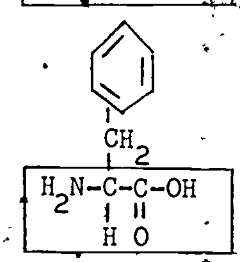
Lysine



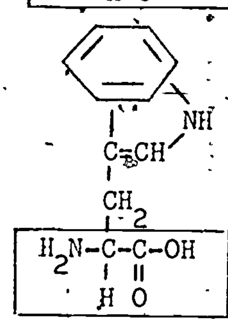
Methionine



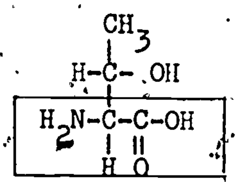
Phenylalanine



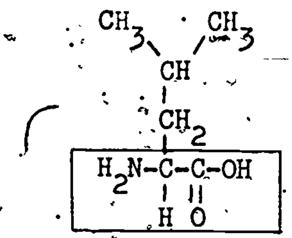
Tryptophan



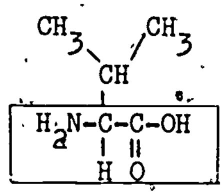
Threonine



Leucine



Valine



A simple mnemonic device may help you to learn the names of these amino acids: I Like Many People To Take Lots Vitamins corresponds to the eight amino acids as listed above.

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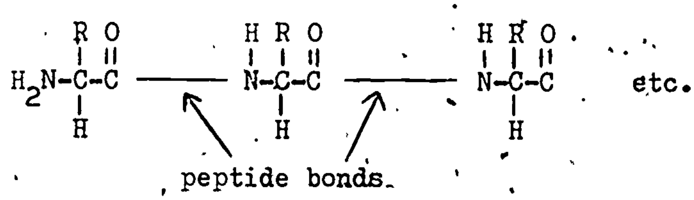
18. The bonds which link amino acids into a polymer are called <u>peptide bonds</u>, and connect the amino group of one amino acid to the carboxyl group of the next.



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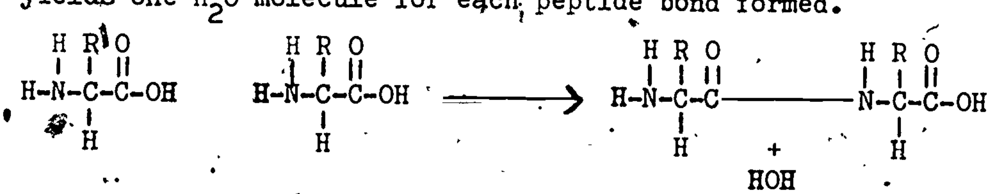
19. Formation of peptide bonds is a <u>dehydration synthesis</u> reaction which yields one H_2O molecule for each peptide bond formed.



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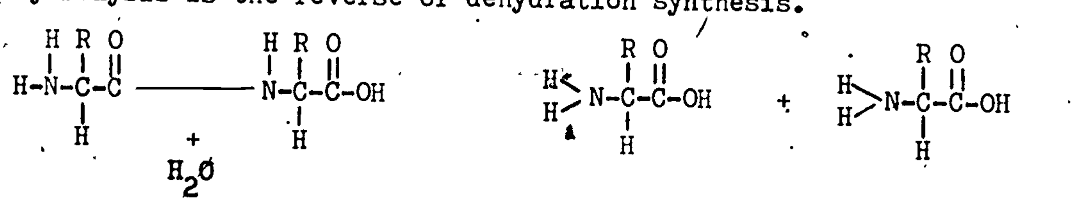
20. Peptide bonds are broken in a reaction called <u>digestion</u> or <u>hydrolysis</u> in which one water molecule is consumed for each peptide bond broken. Hydrolysis is the reverse of dehydration synthesis.



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21. A fantastic variety of different protein molecules are formed from the 20 different amino acids because each linear sequence has its own specific chemical and physical properties. The situation is analogous to our ability to spell an unlimited number of words using only the 26 letters of our alphabet.

If amino acids are analogous to letters, then the proteins formed from them are very big words! Even the simplest have about 50 amino acids and most have hundreds or thousands!

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22. The linear sequence of the amino acids is the primary structure of the protein.

---

23. Most protein molecules shape themselves into a spiral or helix called an alpha helix.

The alpha helix configuration is the secondary structure of the protein.

---

24. At the same time, most proteins are bent and folded into a complex three-dimensional form.

The three-dimensional configuration is the tertiary structure of the protein.

---

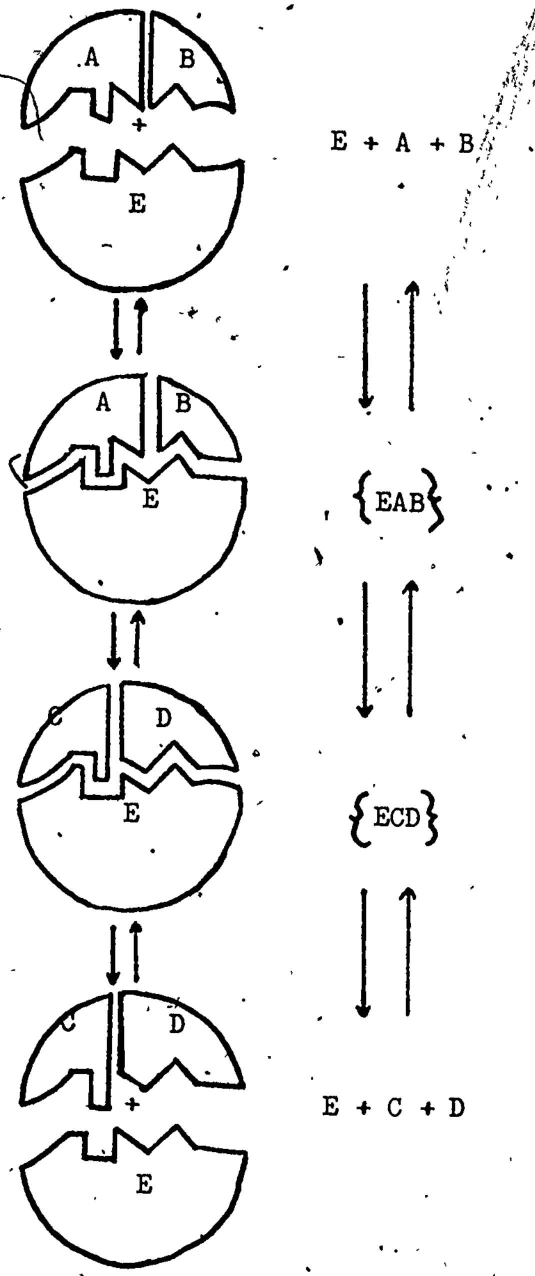
25. Secondary and tertiary structure of a particular protein are predetermined by its primary structure. This happens because each kind of amino acid has unique chemical and physical properties inherent in its side chain; thus the linear sequence puts these different kinds of amino acids into relationships where they will interact in a specific way.

EXAMPLES:

Side chains having an amino group are positively charged; side chains having a carboxyl group are negatively charged. Suppose an amino acid having a positively charged side chain is at one end of the protein while an amino acid having a negatively charged side chain is in the middle. These unlike charges form ionic bonds so the end will attach to the middle making a fold in the tertiary structure.

Side chains having sulfur form covalent bonds with each other, thus these will link their side chains and affect the tertiary structure.

6



Highly diagrammatic, two-dimensional representation of an enzyme catalyzing the conversion of two complementary substrate molecules (A and B) into products (C and D). The enzyme molecule remains unchanged during the reaction.

26. The catalytic properties of enzymes is an outcome of primary, secondary, and tertiary structure. Since each kind of protein has unique structural, physical, and chemical properties, it follows that each kind is very restricted as to the materials it can interact with. This explains why a particular enzyme can only catalyze one specific reaction.

To catalyze a reaction, the enzyme combines temporarily with its substrate. When the reaction is concluded, the enzyme and products separate and the enzyme can repeat its effect on another substrate molecule, etc.

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27. Since the catalytic properties of an enzyme depend upon its unique form and physical properties, then it follows that its catalytic properties disappear when its secondary and tertiary structures are changed. Such changes can be induced by heat, changes in pH, or chemical reactions.

An enzyme which has lost its ability to catalyze a reaction is said to be denatured.

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28. Protein molecules often have other kinds of material attached to them. These are called conjugated proteins.
EXAMPLES:
Nucleoproteins: composed of proteins and nucleic acids.
Phosphoproteins: composed of proteins and phosphoric acid.
Lipoproteins: composed of proteins and lipids.
Glycoproteins: composed of proteins and polysaccharides.

PROTEIN STRUCTURE MODEL

Review the handout on proteins prior to examining this model.

A protein consists of a sequence of amino acids bonded together by peptide bonds. A simple model of a short protein molecule is available for your examination. Each amino acid is represented by a wooden bead. How many amino acids are in the short protein model? How many different amino acids are found in proteins in nature?

Proteins are complex molecules that may function in highly specific ways. For example, proteins function as enzymes, antibodies, and hormones. The key to specificity of a molecule is found in the molecule's structure. In order to understand the complex nature of proteins we must examine them on at least three different levels.

You have already examined a short protein chain model. Such a chain can be described with respect to the sequence of amino acids that make it up. The sequence of amino acids in a protein chain represents the primary structure of the protein.

All proteins arrange themselves in a particular way in space that we call the "secondary structure". Examine the second protein chain that has a twisted appearance. Notice that this chain curves in space in a regular manner as though the primary chain has been wrapped around a cylinder. This secondary structure of a protein is sometimes called the alpha-helix.

Some proteins do not have a level of organization that goes beyond the "secondary structure". However, a "tertiary structure" is always characteristic of enzymes and antibodies. A tertiary level involves the folding and attaching of the secondary level protein back on itself in one or more areas. A complex three dimensional molecule with a specific shape is the result. You should now observe the enzyme model to see how the specific shape plays a vital role in the functioning of the protein.

ENZYME MODEL

Enzymes are complex tertiary level proteins with specific shapes. One portion of the enzyme molecule physically "fits" with the substrate (reactants). This area of fit on the enzyme is called the "active site".

Observe the model of the enzyme. Notice that it has a complex three-dimensional shape. One portion of this enzyme is capable of bonding with the substrate molecules. Locate "substrate A" and attach it to the enzyme in the area where it fits best. Now locate "substrate B" and attach it to the enzyme in the area where it fits best. Notice that A and B are attached together. The enzyme has helped in the attachment by causing the two substrates to meet in the proper orientation. The enzyme has thus facilitated (catalyzed) the binding of A to B. Notice that the enzyme can now be removed and that it has not changed in shape during the reaction. We can summarize the reaction in the following manner: A + B + Enzyme ⟶ AB Enzyme ⟶ AB + Enzyme

CELLS

1. All living organisms from the simplest bacteria to the most complex plants and animals share the cell as the basic unit of structure.

2. Some organisms consist of only one cell. This is the case for bacteria, blue-green algae and protists. Other organisms are composed of tremendously large numbers of cells. A human, for example, is composed of over 40 trillion cells.

3. The two major types of cells are the Prokaryotic cells and the Eukaryotic cells. Prokaryotic cells are primitive and lack a membrane bound nucleus as well as other complex internal cellular structures. Bacteria and blue green algae have prokaryotic cells.

   Eukaryotic cells generally possess a true nucleus (at least at some time during the life of the cell) and contain complex internal cellular structures. Protists, fungi, plants and animals possess eukaryotic cells. This hand-out will concentrate on the structure of the eukaryotic cells.

4. Cells exhibit tremendous diversity in terms of size, shape, and internal components. The largest living cell is the egg of an ostrich. The longest cell is the nerve cell of a whale (over 10 meters). At the other extreme, millions of bacteria would fit in a single teaspoon. Some cells, such as those of human skeletal muscles, each contain many nuclei. Human red blood cells contain no nuclei when they are mature.

   The differences among cells are due to the wide variety of functions performed by these structures. Although cells differ in terms of structure and contents, it is useful to generalize and discuss a hypothetical cell.

5. Cells are surrounded by a cell membrane which is also referred to as the plasma membrane. The plasma membrane serves as the important link between the cell's internal and external environment.

   The plasma membrane is made up of a double layer of phospholipids (lipid molecules with both polar and non-polar portions) with globular proteins imbedded in portions of this lipid bilayer.

   The plasma membrane is selectively permeable. Certain things such as water and some ions can readily pass across the membrane. Some larger molecules are moved through the membrane by a carrier-mediated process. Some membrane proteins act as carriers.

6. All materials bounded by the plasma membrane (the cell contents) are collectively referred to as protoplasm.

7. The cell contents, excluding the cell nucleus, are collectively referred to as cytoplasm. Within the cytoplasm there are complex structures which perform specific functions. Such complex cytoplasmic structures are called organelles.

   The remainder of this hand-out will discuss the structure and functions of the nucleus and the cytoplasmic organelles.

Nucleus

The nucleus is often referred to as the control center of the cell. The internal nucleoplasm, surrounded by a double membrane, consists of the genetic material, protein-coated DNA, and a structure called the nucleolus which produces RNA.

Cytoplasmic Organelles

Endoplasmic Reticulum

The Endoplasmic Reticulum consists of layers of flattened vesicles which transport protein and perhaps other molecules. When the Endoplasmic Reticulum has Ribosomes attached to its membrane, it is called Rough E R. Without ribosomes, it is referred to as Smooth E R.

An abundance of Rough E R is found in cells which synthesize protein for export. Smooth E R is believed to be involved in the production of steroid molecules (estrogen, cortisol, etc.).

Ribosomes

These are spherical structures on which the assembly of proteins occurs. Ribosomes are often attached to the endoplasmic reticulum. They also exist freely in the cytoplasm, often as long chains of polyribosomes.

Golgi complex

The Golgi complex consists of layers of flattened vesicles whose ends are rounded. Protein is believed to be stored and concentrated here, contained within the vesicles that bud off to stream through the cytoplasm.

Mitochondria

The mitochondrion is often called the powerhouse of the cell. Large amounts of high energy adenosine triphosphate molecules are produced in each mitochondrion during a process called cellular respiration.

Mitochondria are sausage-shaped structures, each of which has an outer smooth membrane surrounding an inner folded membrane. The folds on the inner membrane are called cristae. A fluid matrix separates the cristae from the outer membrane.

Vacuoles

Vacuoles are membrane-lined containers consisting of various compounds. In most plant cells a fluid filled vacuole occupies much of the internal space. In some cells, vacuoles are formed when the outer plasma membrane engulfs material outside the cell and then inwardly pinches off from the main cell membrane.

Lysosomes

Lysosomes are membrane-bound containers of enzymes. Lysosomes often merge with vacuoles, holding foreign material or cell debris, and disintegrate the contents. Digested contents are usually ejected through cell membrane. A lysosome may also destroy an entire cell when it bursts and releases its contents.

Centrioles

Centrioles are a pair of barrel-like cylinders that appear to produce asters and spindle fibers during the division of animal cells. Chromosomes move along the spindle fibers during cell division.

Chloroplasts

Chloroplasts are disc-shaped structures found in photosynthetic plant cells. From one to three hundred chloroplasts may be found in a single plant cell. Photosynthesis occurs within the chloroplast.

BIOENERGETICS

1. Energy has become a topic of paramount importance during recent years, as the traditional forms of energy-generating materials have become more difficult to obtain. We are all concerned about the "energy crisis" and yet most of us would have difficulty defining the word "energy" in a precise way. Energy, to the scientist, is simply defined as the capacity to do work.

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2. Energy can be stored in the chemical bonds of molecules.. Such stored energy is called potential energy. The molecules in gasoline have potential energy. When combustion occurs in a gasoline engine the bonds among the molecules are rearranged with a resulting release of energy which can do work. Energy that is released to do work is called kinetic energy. Thus when gasoline is burned, potential energy is converted to kinetic energy, which is then used to do work.

   As you know, your body does not run by the combustion of gasoline. Your ability to do work, however, is based on a similar energy transformation in which a high energy biological molecule called Adenosine Triphosphate releases energy that allows the organism to do such things as contract muscles, transmit neural impulses, move molecules across cell membranes, and synthesize complex molecules.

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3. There are two laws which relate to energy. These are referred to as the first and second laws of thermodynamics.

   The first law of thermodynamics states that energy can be changed from one form to another (for example, from light to heat), but cannot be created or destroyed.

   The second law of thermodynamics states that all processes in the universe operate in such a way that disorder (Entropy) is increased. Another way of saying this is that things naturally tend to fall apart and become less organized.

   The implications of these two laws are vast in terms of the functions of living things, but the net result is basically the following: (A) There must be a constant input of energy into a biological system to keep it functioning, and (B) Organisms must use energy to work against the second law of thermodynamics. Ultimately all organisms lose the battle against the second law, but while we are alive our bodies are constantly using energy to maintain our complexity through processes such as the constant building of new cells and tissues.

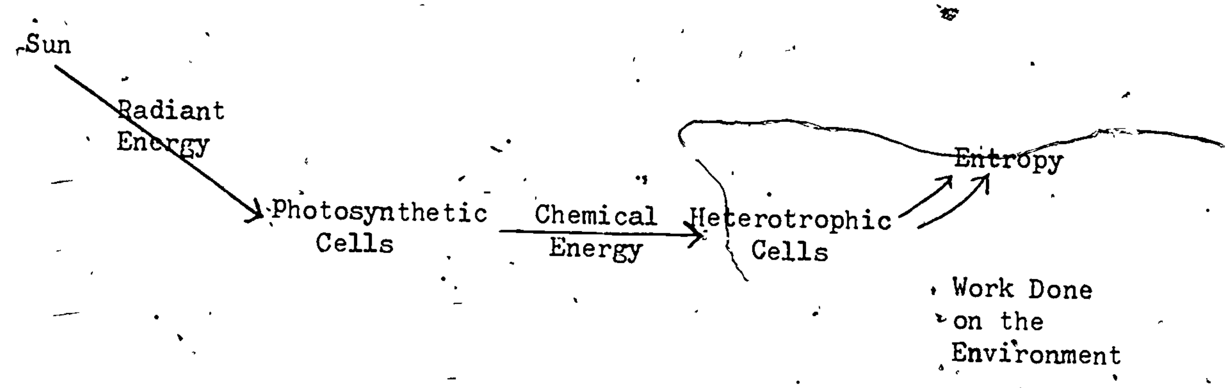
---

4. The ultimate source of energy on earth is the sun. The radiant solar energy is changed into usable forms of chemical energy by those organisms which can do photosynthesis. The photosynthetic organisms (plants, some protists, some bacteria, and blue green algae) are called autotrophs (self feeders). Autotrophs use solar energy to convert energy poor molecules (carbon dioxide and water) into energy rich molecules (glucose and oxygen).

   Those organisms that cannot do photosynthesis are called heterotrophs (other feeders). Heterotrophs must consume autotrophs either directly

(as plant food) or indirectly (as meat) in order to survive.

Thus, we have a one way flow of energy from the sun to the autotrophs and then to the heterotrophs. This energy is not recycled because at the heterotroph level it is ultimately lost as work done on the environment. We can diagram our energy flow in the following way:

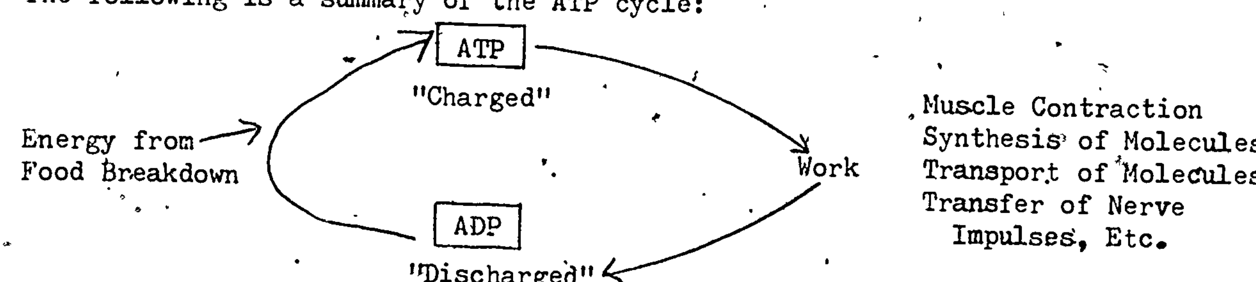


5. Adenosine Triphosphate, or ATP for short, is the primary high energy molecule that is used by living things to do work. Observe the model of ATP in the classroom and note that it is composed of three parts: a nitrogenous base, called adenine, a sugar called ribose and three phosphate groups (triphosphate). The last two phosphates are attached by "high energy" bonds. When these bonds are broken, large amounts of energy are released, energy which is available to do work. The overall release of energy can be summarized in the following way:

ATP	$\longrightarrow$	Energy for Work	+	ADP	+	Phosphate
High Energy						Lower Energy

ADP (Adenosine Diphosphate) is a lower energy molecule. ADP can be recycled back to ATP by reattaching a phosphate. This recycling back to ATP is an "uphill" reaction and requires an input of energy. The energy for the production of ATP is provided by the breakdown of food molecules.

The following is a summary of the ATP cycle:



6. ATP is generated in cells by the breakdown of complex food molecules into simpler molecules. The process of ATP production involves a stepwise series of enzyme catalyzed reactions, which result in a very efficient production of ATP.

7. A process called Glycolysis is the primary route of food breakdown. Digestion of foods provides the six carbon sugar, glucose, to begin the process of glycolysis.

Glucose is broken down in a series of eleven reactions to two molecules of Pyruvic Acid.

Two molecules of ATP must initially be used to begin glycolysis, but at the end of the process, four new molecules have been synthesized. Thus there is a net gain of two ATP's for each glucose molecule broken down in glycolysis.

In addition, two molecules of reduced NAD are produced. These can be used in another part of the cell for the further production of ATP.

Glycolysis is an anaerobic process (without oxygen) which occurs in the cytoplasm of the cell. It may lead to fermentation of pyruvic acid if oxygen is temporarily or continuously unavailable. In some organisms, such as some bacteria and yeast, fermentation leads to the production of ethyl alcohol. In higher forms, such as humans, fermentation leads to the accumulation of lactic acid.

In order to appreciate the steps involved in glycolysis, be sure to work with the classroom models which you can obtain from your instructor.

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8. The Krebs Citric Acid Cycle uses the products of glycolysis (pyruvic acid) to produce additional ATP, reduced NAD, and a third high energy molecule called reduced flavoprotein (FP). In addition to pyruvic acid from glycolysis, other molecules, such as amino acids and products of lipid metabolism, may enter the Krebs cycle at various points and contribute to a further production of the high energy molecules generated in this cycle.

The Krebs cycle is an aerobic reaction (oxygen requiring) and occurs within the matrix of the mitochondria in eukaryotic organisms.

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9. The electron transport chain (cytochrome system) uses the reduced NAD generated in glycolysis and the Krebs cycle and the reduced FP generated in the Krebs cycle to synthesize additional ATP molecules.

This system involves the transfer of hydrogen atoms with electrons from reduced NAD and reduced FAD to electron accepting molecules called cytochromes. The initial cytochrome molecules in turn transfer the electrons with hydrogen to another cytochrome. This transfer of electrons occurs along a series of cytochromes until, ultimately, oxygen acts as a final acceptor. The combination of oxygen with hydrogen results in the formation of water.

There is a release of energy at each transfer of electrons with hydrogen from one cytochrome to the next. It is this released energy that is used to synthesize additional ATP molecules.

The cytochromes involved in the electron transport chain are arranged in an ordered way on the inner membrane (cristae) of the mitochondrion. Such a precise membrane-bound arrangement is necessary for the stepwise transfer of electrons with hydrogens.

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10. We can summarize the cellular production of ATP molecules (cellular respiration) with the following overall equation:

Glucose + Oxygen ⟶ Carbon Dioxide + Water + Energy (ATP)

Such an equation is a tremendous simplification, as you are now aware, and it is worth reviewing where the reactants are used and how the products are generated.

Glucose is used at the very beginning of cellular respiration during glycolysis within the cytoplasm.

Oxygen is used at the end of cellular respiration when it acts as the final electron acceptor in the electron transport chain and combines with hydrogens to form water.

Carbon Dioxide is generated during a step leading from glycolysis to the Krebs cycle and in the Krebs cycle itself.

ATP is generated in all three parts of cellular respiration. The actual number of ATP molecules generated from the breakdown of one glucose molecule is variable, with a maximum number being about 38 ATP's per glucose. If 38 ATP's are generated, two were produced during glycolysis, 2 in the Krebs cycle, and 34 in the electron transport chain. Thus, the bulk of an aerobic cell's ATP molecules are generated during the last phase of cell respiration.

---

11. Cellular respiration with the high energy molecule glucose and results in the production of usable energy molecules (ATP) plus the low energy molecules carbon dioxide and water. Cellular respiration thus requires a continual input of complex food molecules. The origin of high energy food molecules rests on the ability of plant and other autotrophs to use sunlight as a source of energy for synthesis.

Autotrophs do photosynthesis. An overall equation for photosynthesis is the following:

Carbon Dioxide + Water + Sunlight ⟶ Glucose + Oxygen

In higher plants photosynthesis occurs within the chloroplast where a pigment called chlorophyll acts as a light receptor.

---

12. Photosynthesis occurs in two major stages. The first stage is called the light reaction. The light reaction occurs in the granum of the chloroplast. Review the chloroplast structure by observing the classroom model.

In the light reaction, units of light energy drive the electrons from the chlorophyll molecules. These electrons are grabbed by an electron acceptor. Chlorophyll, at the same time, replaces its lost electrons by taking electrons from a water molecule. As the water loses its electrons, it is split into hydrogens and oxygen. The oxygen is then released. Electrons are transferred from the original electron acceptor to a series of electron acceptors which are embedded in the granum and ATP is formed. Ultimately the electrons are accepted by another type of chlorophyll. When the second chlorophyll is hit with units of light energy, it too transfers its electrons to an electron acceptor. These electrons are used to form reduced NADP.

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13. The dark reaction, the second stage of photosyntheses, occurs within the stroma of the chloroplast. The dark reaction involves a cycle in which Carbon Dioxide is combined with a molecule called Ribulose Diphosphate. In a series of energy requiring steps, with the energy being provided by the ATP and reduced NADP generated in the light reaction, a product called Phosphoglyceraldehyde (PGAL) is produced. PGAL can be used to synthesize Glucose or other important molecules.

CELLULAR RESPIRATION

This is an overall diagram of cellular respiration. There is a legend to the diagram in the upper right hand corner. To begin, familiarize yourself with the legend.

The actual diagram begins in the upper left hand corner.

The name of the first part of cellular respiration is glycolysis, and, in order to see the overall steps, follow the diagram from the upper left downward to the lower left corner.

Summary of Glycolysis

Glycolysis begins with the six carbon sugar glucose and is a series of eleven steps (these steps are not illustrated individually on the diagram). Glucose is broken down into two molecules of pyruvic acid.

Notice as you proceed from glucose that two types of high energy molecules are produced - two ATP's and two NAD red. These four high energy molecules represent the net gain from glycolysis.

In organisms which breathe oxygen, the pyruvic acids will then be used as initial reactants in the second part of cellular respiration, the Krebs Cycle.

Each pyruvic acid enters the Krebs Cycle individually, so everything that follows will happen twice for each glucose and once for each pyruvic acid.

In order to observe the Krebs Cycle, proceed to your right, to the center of the diagram.

Notice as you go from the pyruvic acid toward the cycle, that in the next step, a carbon dioxide is formed. Also in this step, a molecule of NAD is reduced. The three carbon pyruvic acid thus leads to a two carbon molecule (an acetyl group), since a carbon is removed in forming carbon dioxide. The acetyl group combines with a molecule called coenzyme A to form acetyl coenzyme A.

The role of coenzyme A is to facilitate the movement of the acetyl group into the Krebs Cycle. At this point, acetyl coenzyme A enters the Krebs Cycle.

The two carbon group combines with a four carbon molecule called oxaloacetic acid. This results in the formation of a six carbon molecule called citric acid.

You should be following the cycle in a clockwise fashion. Notice that as the Krebs Cycle is entered, coenzyme A is released back into the cytoplasm.

In the Krebs Cycle, a series of reactions occur leading from citric acid ultimately back to oxaloacetic acid. In the next step, citric acid is changed to keto glutaric acid (a five carbon group). Notice that in this step carbon dioxide is released and a reduced NAD is formed. Keto glutaric acid is next changed to succinic acid (a four carbon group). During this transformation the following are produced: NATP, a reduced NAD, and carbon dioxide.

Succinic acid is then changed to malic acid (a four carbon group). In this step a molecule of reduced FAD is formed. In this last step of the cycle, malic acid is changed to oxaloacetic acid (a four carbon group), and in this step a reduced FAD is formed. This completes one turn of the Krebs Cycle and it will turn once for each pyruvic acid entering the cycle.

The final part of cellular respiration is called the electron transport chain. This is arranged in a diagonal fashion to the right of the Krebs Cycle and below the legend. Begin at the top with reduced NAD. In the electron transport chain, the reduced NAD's and the reduced FAD produced in the first two parts of cellular respiration are used to synthesize ATP's. This occurs through a series of oxidation reduction reactions. Beginning at the top, reduced NAD becomes oxidized by transferring electrons and hydrogens to the next molecule in the chain which is FAD. Notice that sufficient energy is released in this reaction to produce NATP. Next FAD transfers electrons and hydrogen to a cytochrome. This cytochrome then transfers electrons and hydrogen to the next cytochrome. In the second transfer, enough energy is produced to synthesize an ATP. This is followed by another transfer to the next cytochrome and to another. In this last step, again enough energy is released to synthesize another ATP. Finally, at the end of the electron transport chain, electrons and hydrogen are passed to oxygen, thus reducing oxygen and forming the final product of respiration, water.

MITOCHONDRION MODEL

Aerobic cellular respiration occurs in three phases: Glycolysis, the Kreb's Citric Acid Cycle, and the Electron Transport Chain (Oxidative Phosphorylation). In eukaryotic cells, glycolysis occurs in the cytoplasm while the Kreb's cycle and the electron transport chain occur in the mitochondrion.

The <u>mitochondrion</u> is a complex organelle with two distinct membranes. Examine the model of the mitochondrion and notice that its shape is somewhat like a cylindrical loaf of bread. Of course, the organelle is actually much smaller than the model. In a typical cell, a mitochondrion is about the size of a bacterial cell.

Notice that the model has a smooth outer surface. Inside the mitochondrion there is an extensively folded inner membrane called the <u>cristae</u>. Locate this inner membrane in the model. Surrounding the inner membrane there is a fluid called the matrix.

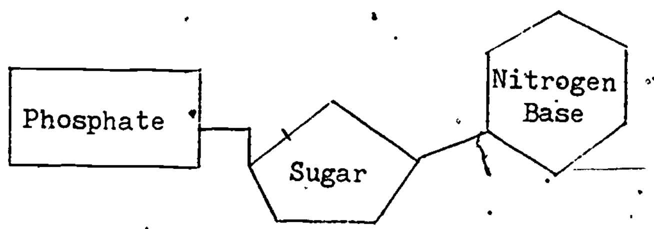
The Kreb's cycle occurs in the matrix, while the electron transport chain occurs on the cristae. Refer to the Cellular Respiration Handout for further information.

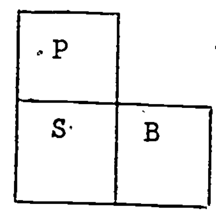
DNA

1. Deoxyribonucleic acid (or DNA) is the molecule of heredity. DNA belongs to a group of macromolecules called nucleic acids. In the cells of humans and other eukaryotic organisms, DNA is found within the cell nucleus.

2. Since DNA is essentially a strand of genes that codes for all the physical traits of an organism, one would suspect that this must be a very complicated molecule. A remarkable feature of DNA turns out to be its simplicity.

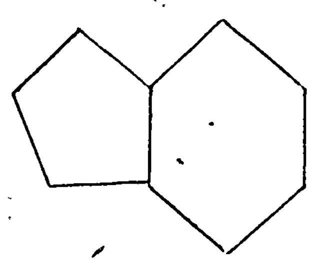
3. DNA is composed of four different types of molecules called nucleotides. Each nucleotide, in turn, consists of three parts: a nitrogen containing base, a sugar called deoxyribose, and a phosphate. A generalized diagram of a nucleotide is illustrated below:



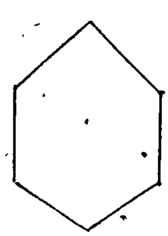


All four nucleotides have the sugar and phosphate in common. They differ with respect to the nitrogen bases.

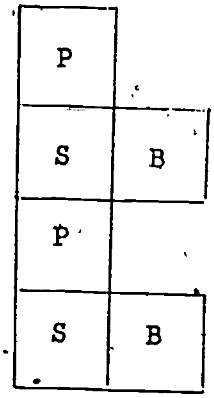
There are two larger bases, called purines, Adenine and Guanine. A generalized diagram of the overall shape of these two is illustrated below:



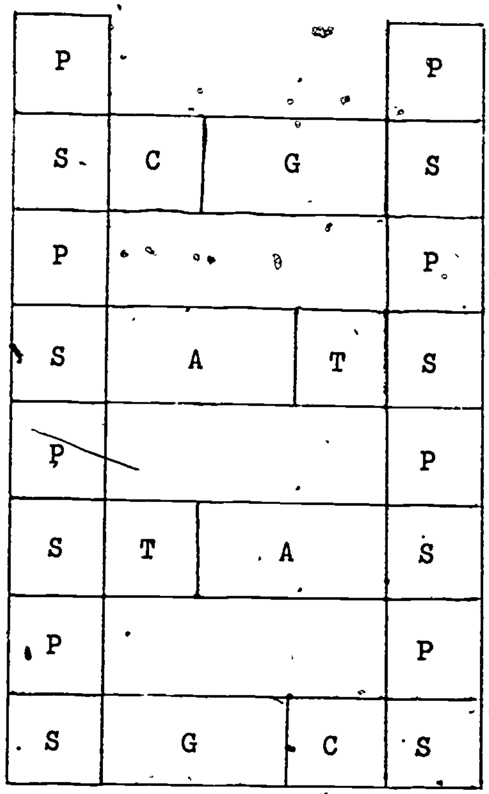
The two smaller bases, called pyrimidines, are Cytosine and Thymine. A diagram of the shape of these two is illustrated below:



4. A DNA molecule consists of two parallel strands of nucleotide chains. Each individual strand is made up of a series of individual nucleotides linked at their sugars and phosphates in the following way:



The two parallel nucleotide chains are connected base to base by weak bonds (hydrogen bonds) in the following way:



Note that each base pair always has one large base (purine) paired with one small base (pyrimidine). In addition, because of the way in which hydrogen bonds can form, Adenine always pairs with Thymine and Guanine always pairs with Cytosine. The fact that A goes with T and G with C is known as the DNA base-pairing rule.

---

5. If you can picture DNA as a ladder, then you can view each rung of the ladder as a base pair. The outer supports (sides) of the ladder are made up of alternating sugars and phosphates.

   - Imagine that the DNA ladder is twisted around a very long cylinder. You would have a double helix. Such a representation fairly accurately depicts the arrangement of this molecule in space.

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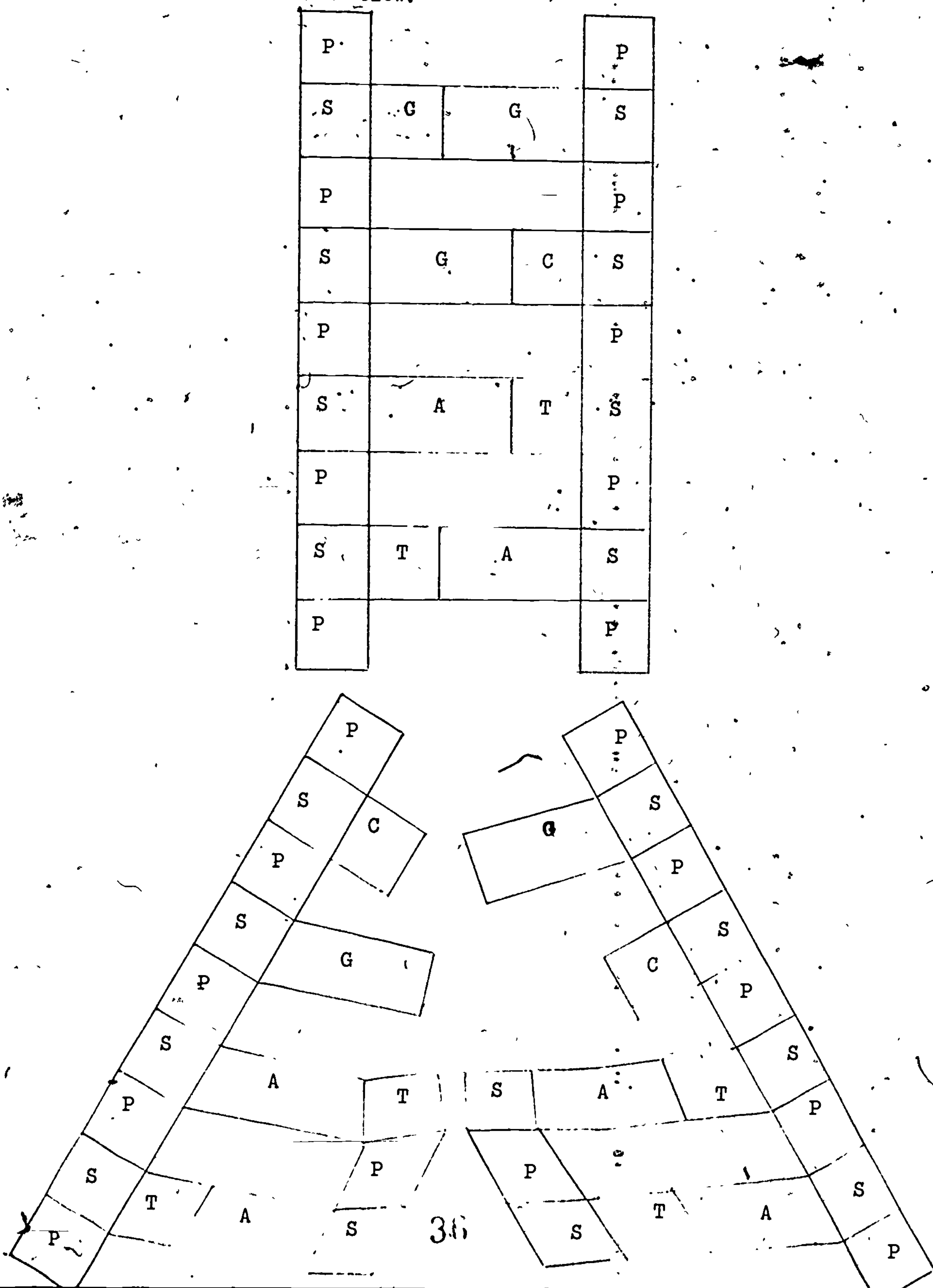
6. As the molecule of heredity, it is essential that exact copies of DNA can be easily produced. Imagine the DNA double helix unzipping and separating at the base pairs, followed by the attachment of new nucleotides at the exposed positions according to the base-pairing rules. You would end up with two complete ladders from one beginning ladder. This duplication of the genetic material, which must occur before a cell divides, is called DNA replication. The process of DNA replication is illustrated below:



DNA AND PROTEIN SYNTHESIS

1. DNA, functioning as the hereditary material, ultimately determines the traits of an individual. The idea that this one type of molecule can play such a singular role in determining our characteristics is remarkable. What is still more amazing is the manner in which DNA affects these traits. DNA functions by coding for the synthesis of proteins.

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2. Proteins can be grouped into two categories, enzymes and structural proteins.

   Enzymes are organic catalysts which are critical to the smooth operation of living systems. Enzyme synthesis (under the control of DNA) is one of the most fundamental processes carried on by living cells.

   Structural proteins play vital roles in the composition of living tissue. Muscle tissue, cilia and flagella, and protein components of cell membranes are examples of areas within the organism where structural proteins play important roles. The production of each particular type of structural protein is controlled by the DNA.

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3. The DNA (deoxyribonucleic acid) is found in the nucleus of the cell, yet protein synthesis occurs outside the nucleus on Ribosomes within the cytoplasm. Molecules of RNA (ribonucleic acid) carry a transcribed genetic message from the DNA to the ribosome, where other molecules of RNA function in the actual assembly of the protein.

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4. RNA is a second type of nucleic acid. RNA differs from DNA in that it has the base Uracil instead of the base Thymine (U pairs with A during base pairing.), the sugar ribose instead of deoxyribose, and in that the RNA is usually a single stranded molecule rather than a double helix, like DNA.

   There are three types of RNA. Ribosomal RNA is the major structural component of ribosomes. Messenger RNA functions in carrying the genetic message from the nucleus to the cytoplasm. Transfer RNA brings amino acids into position on the ribosome during the construction of a protein.

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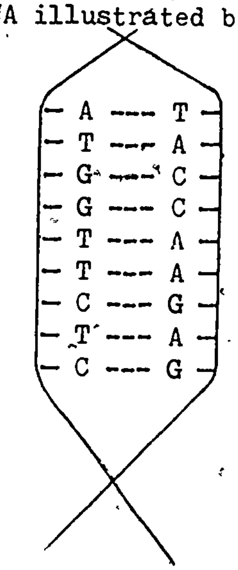
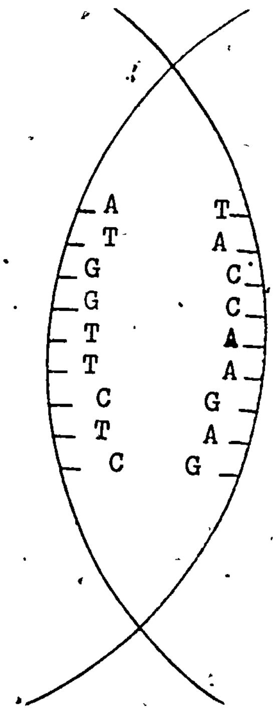
5. The process of protein synthesis begins when a portion of the DNA double helix unzips to expose a gene. On this level of genetics we will consider a gene to be a segment of the DNA that codes for one particular protein. Suppose that the DNA illustrated below contains our gene:

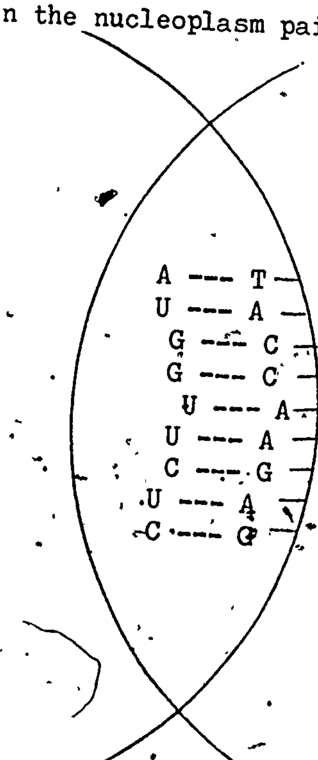


The base pairs unzip as hydrogen bonds are broken and the gene is exposed.



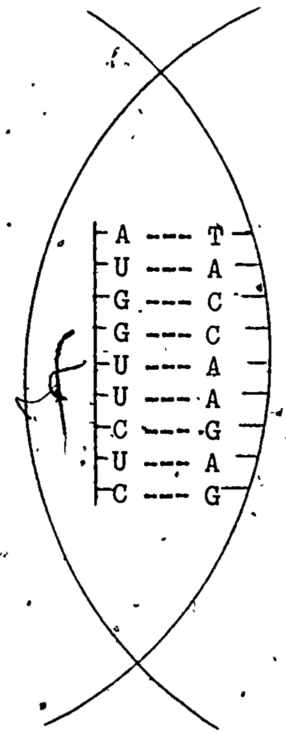
One side of the exposed DNA, the DNA template, will code for the production of a strand of messenger RNA (mRNA). The other DNA side does not participate. (For simplicity, we will therefore exclude it in further illustrations.)

Free RNA nucleotides in the nucleoplasm pair up with the exposed DNA bases:

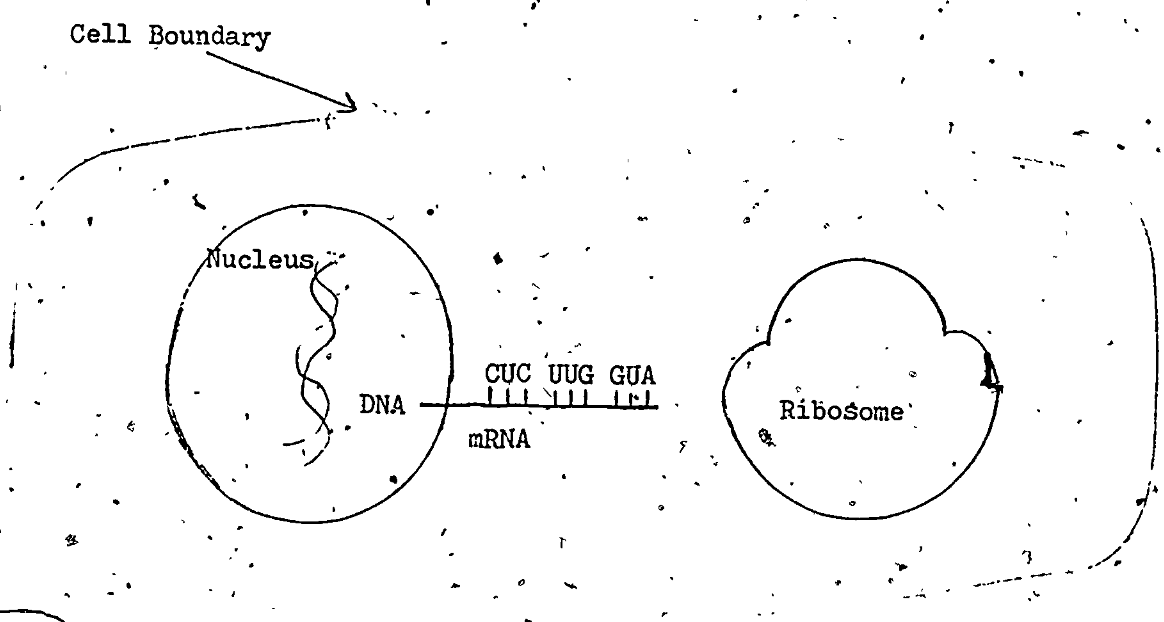


The RNA nucleotides then form linkages which result in one strand of messenger RNA.

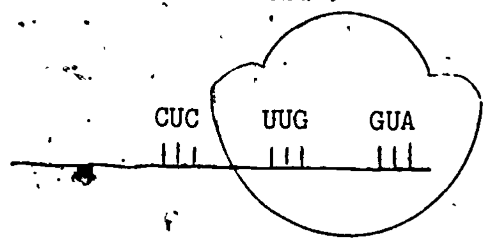
The production of a strand of messenger RNA on the DNA template is referred to as transcription.



6. The strand of mRNA then leaves the nucleus and attaches to a Ribosome in the cytoplasm:



A length of messenger RNA consisting of six bases will fit on the ribosome at one time:



When the messenger RNA is in such a position on the Ribosome, it is properly oriented for protein synthesis.

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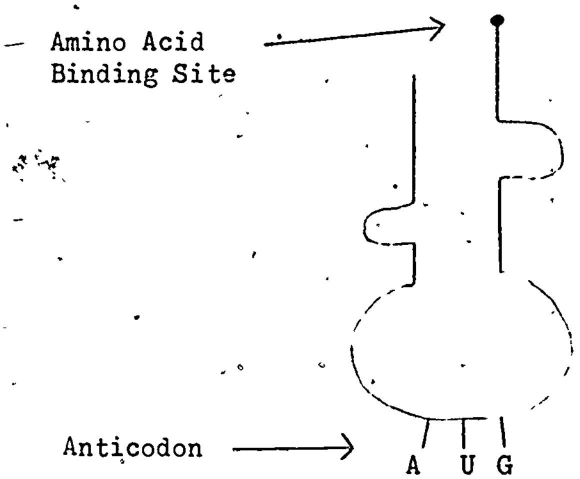
7. Each set of three bases (triplet) is the RNA code for a particular amino acid. Each of these triplets is called a <u>codon</u>.

There are 64 possible codons, but only 20 different amino acids. The code is therefore redundant in that several amino acids are coded for in more than one way. In addition, there are three termination codons which stop the production of a protein. Possible codons and the amino acids for which they code are in the following table:

FIRST LETTER	SECOND LETTER U	SECOND LETTER C	SECOND LETTER A	SECOND LETTER G	THIRD LETTER
U	UUU phe	UCU ser	UAU tyr	UGU cys	U
U	UUC phe	UCC ser	UAC tyr	UGC cys	C
U	UUA leu	UCA ser	UAA - stop	UGA - stop	A
U	UUG leu	UCG ser	UAG - stop	UGC - trp	G
C	CUU leu	CCU pro	CAU his	CGU arg	U
C	CUC leu	CCC pro	CAC his	CGC arg	C
C	CUA leu	CCA pro	CAA gln	CGA arg	A
C	CUG leu	CCG pro	CAG gln	CGG arg	G
A	AUU ile	ACU thr	AAU asn	AGU ser	U
A	AUC ile	ACC thr	AAC asn	AGC ser	C
A	AUA ile	ACA thr	AAA lys	AGA arg	A
A	AUG - met	ACG thr	AAG lys	AGG arg	G
G	GUU val	GCU ala	GAU asp	GGU gly	U
G	GUC val	GCC ala	GAC asp	GGC gly	C
G	GUA val	GCA ala	GAA glu	GGA gly	A
G	GUG val	GCG ala	GAG glu	GGG gly	G

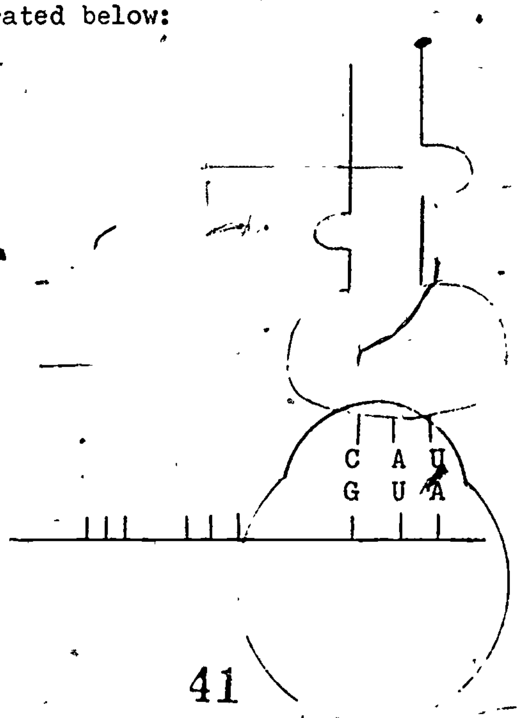
8. Within the cytoplasm of a cell there are free amino acids as well as molecules of transfer RNA (tRNA). There are at least as many different types of tRNA as there are amino acids, and each different tRNA molecule has an affinity for only one amino acid.

The tRNA molecules have a shape something like a cloverleaf. One portion of the molecule has an amino acid binding site, while at the base of the molecule, there is a set of three bases called an anticodon. A generalized tRNA molecule is illustrated below:



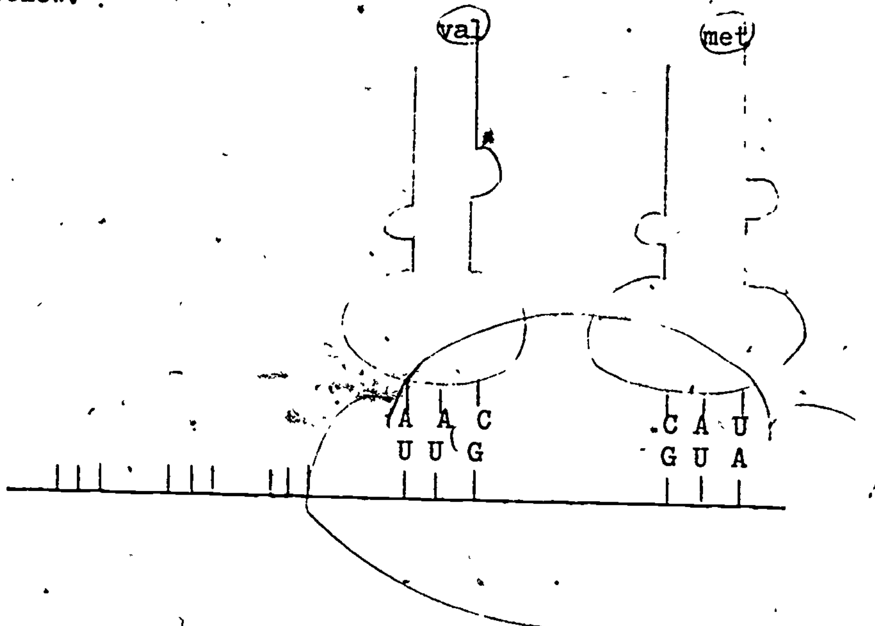
9. Amino acids attach to specific transfer RNA molecules in an enzyme catalyzed reaction. Once the transfer RNA molecules have their amino acids in tow, they are ready to participate in protein synthesis.

10. You will recall that there are two messenger RNA codons in position on the ribosome. Various transfer RNA molecules, with their amino acids in tow, randomly contact the exposed codons, but no attachments between the two RNA molecules occur unless an anticodon pairs in a complementary way (according to base pairing rules) with a codon. When a transfer RNA with an anticodon that is complementary to a messenger RNA codon comes into position, hydrogen bonds are formed between the matching bases. The hydrogen bonds hold the transfer RNA in position. This codon-anticodon pairing is illustrated below:

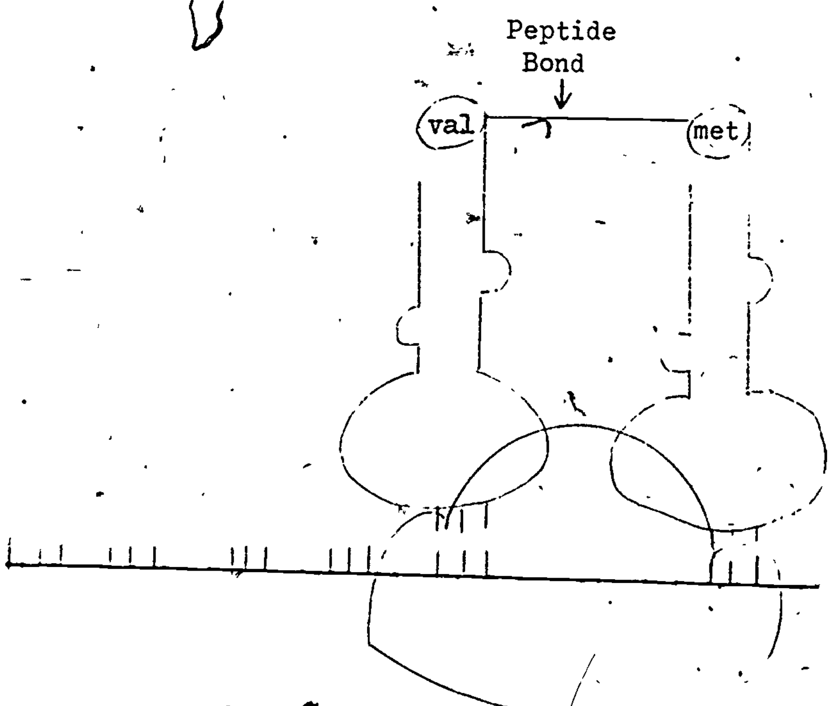


Notice that the codon AUG is complementary with the anticodon UAC. Also notice that the codon AUG codes for the amino acid methionine (see previous table), and that our transfer RNA has brought that amino acid into position.

At this point the next codon attracts the appropriate tRNA as illustrated below:



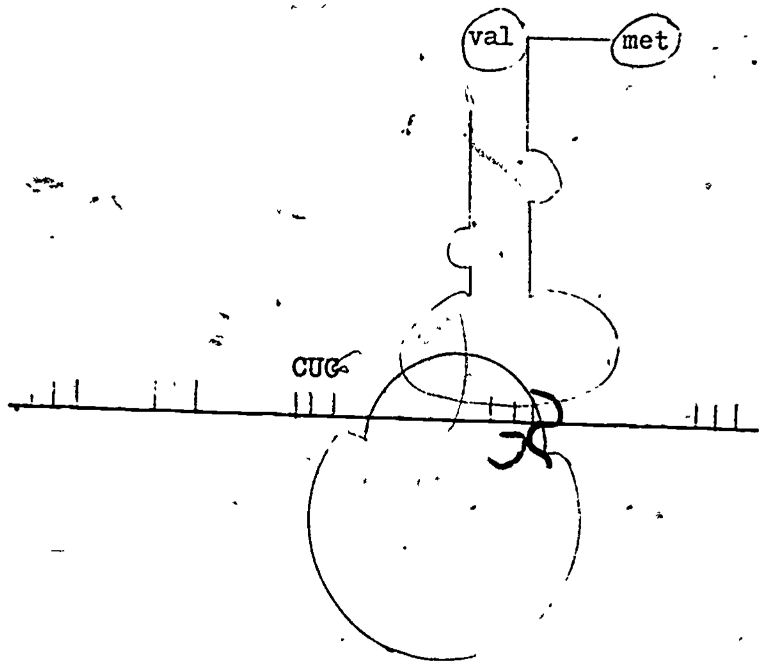
At this point a peptide bond is formed between the two adjacent amino acids in an enzyme catalyzed reaction:



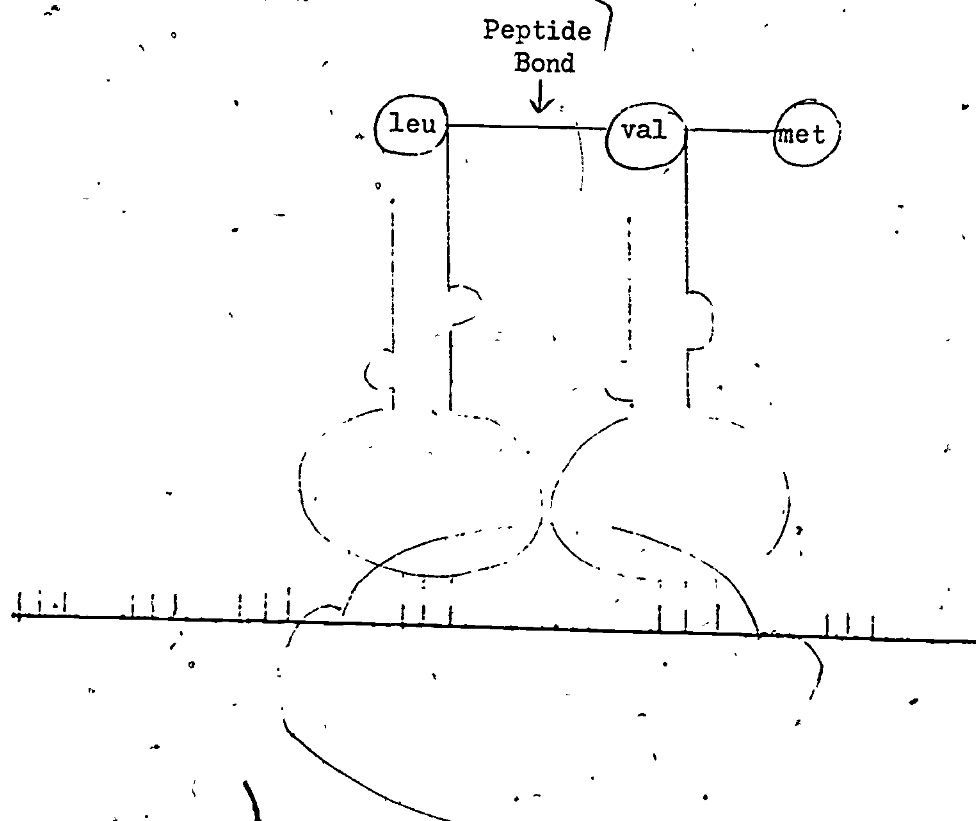
The first link in our protein has been formed. The transfer RNA that brought the first amino acid (methionine) into position is released back to the cytoplasm.

The messenger RNA, with the second transfer RNA and its dipeptide still

attached, now moves one codon down the ribosome.



Another codon is now in position for binding with the appropriate tRNA. The transfer RNA carrying its amino acid comes into position, and a second peptide bond is formed:



Now we have a chain of three amino acids linked together.

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11. The process of converting the messenger RNA code into a protein chain is known as translation.

The steps of translation, outlined above, will continue until a termination codon (<u>stop</u> in the table) causes the completed protein to be released.

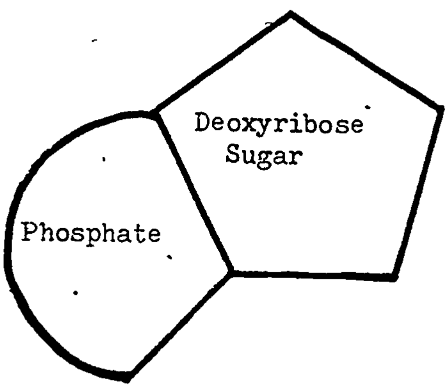
In most cases the messenger RNA moves from one ribosome to another and leads to the synthesis of many molecules of the same protein.

PROTEIN SYNTHESIS MODEL

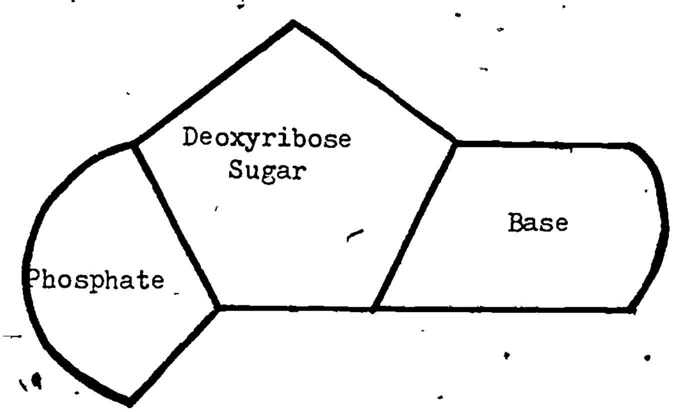
In order to appreciate the manner in which DNA codes for traits it is worthwhile to simulate the process with a model. You should review the handout on protein synthesis and have that handout available as you work with the DNA/protein synthesis materials.

Begin by organizing the model building materials. It may be helpful to separate each different type of component into an individual pile.

Your first goal is to construct a single nucleotide. Take a deoxyribose sugar and attach a phosphate on its left as illustrated:



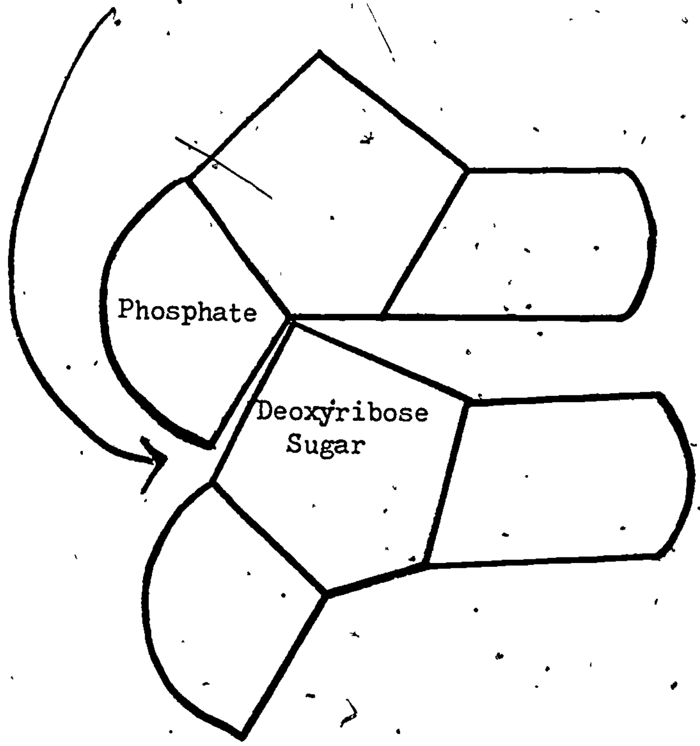
Now attach a DNA base (A, T, G, or C) to the right of the deoxyribose sugar as illustrated:



You have now constructed a nucleotide. Construct eight more nucleotides using bases of your choice.

Now attach your nucleotides together from the phosphate of one to the deoxyribose sugar of the next. Connect all nine nucleotides.

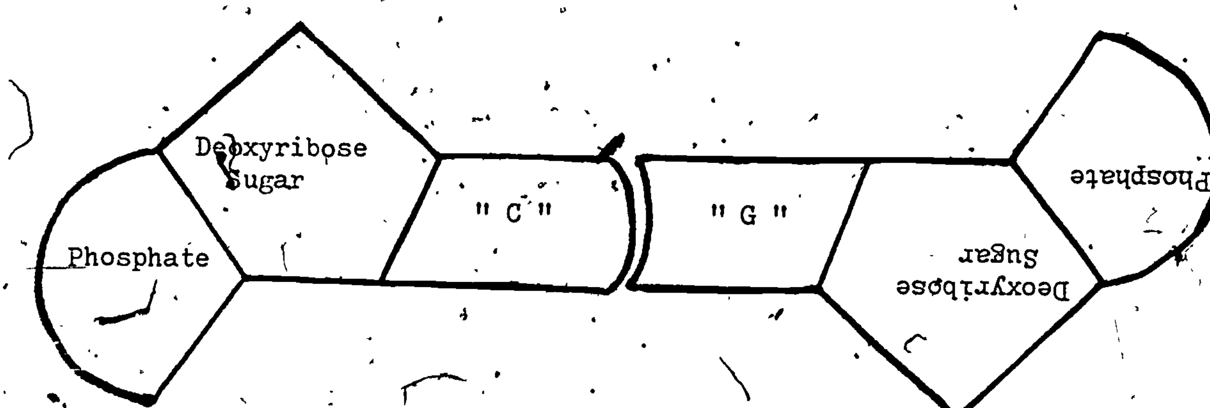
Example of connection:



You have now completed one half of a DNA ladder. You may now build the other side.

Recall that there are complementary base pairs in DNA. The "A" base always pairs with a "T" base in DNA, and the "C" base always pairs with a "G" base. Build the other side of your ladder according to the base-pairing rules.

Example of two matching sides:



Your completed DNA model should appear like a ladder with base pairs representing the rungs, and the sugars and phosphates forming the outer supports.

You will now accomplish the process of transcription. Build a segment of messenger RNA along one side of the DNA. The construction of the mRNA is similar to the construction of one side of a DNA ladder with two important differences: Ribose sugar is used instead of deoxyribose and the base Uracil (U) is used instead of Thymine (T). Your mRNA should be complementary to one side of the DNA and should be nine nucleotides long.

Once you have completed the transcription of mRNA you are ready to begin the process of translation. Place the mRNA on your ribosome so that six nucleotides (codons) are in position. Each unit of three nucleotides acts as a codon by determining a specific amino acid that will be brought into position. Read your three codons and determine the three amino acids that are being coded for (use the code table in the DNA/Protein systhesis handout). Find the amino acids that you need and the three transfer RNA molecules that match up with them. Attach the amino acids to their transfer RNA molecules. Place the appropriate anticodon letters on the bottom portion of your transfer RNA molecules so that each anticodon on a tRNA matches with a codon on mRNA.

You now have a completed model. At this point you should work through the DNA/Protein systhesis handout step by step, manipulating the model as you read. You should be able to work through to the end of translation and complete a protein that is three amino acids long.

CELL DIVISION

INTRODUCTION

A long time ago you first came into existance when a sperm cell from your father combined with an egg cell in your mother. At exactly that point in time you became a one celled zygote. Subsequently, following many cell divisions, and a great deal of differentiation, you became an embryo, then a fetus, and finally an individual capable of free existance.

Today you exist as a human being composed of several billion cells. Some of these cells will exist throughout your lifetime, others are being replaced at rapid rates. A remarkable characteristic of the cells which make up your stnucture is that they are all genetically identical to one another and also genetically identical to the cell which marked your very beginning (the zygote). Your cells share identical genetic information (with the exception of sex cells, and perhaps a few body cells which have undergone slight mutations) due to the very precise manner in which new cells are created. This very precise type of cell division is called mitosis.

THE NATURE OF THE GENETIC MATERIAL AND MITOSIS

The genetic material which leads to the expression of your hereditary traits is found within the nuclei of your cells. This genetic material is called deoxyribonucleic acid, or DNA for short.

Cells pass on their DNA in a precise manner during cell division. Precise transfer of genetic information occurs because the DNA is packaged by the cells into structures called chromosomes. You have 46 chromosomes in each of your body cells. 23 of the 46 chromosomes came from your mother and the other 23 came from your father. The traits which cahracterize you are coded for by the DNA on your 23 pairs of chromosomes.

Your instructor will discuss the genetic material in more detail during your lecture. The most important concept for you to understand at this time is the way in which the DNA is passed so precisely from one cell generation to the next during mitosis. In order to understand mitosis you will work with some cell and chromosome models in the classroom.

TERMS OF IMPORTANCE

Chromosome: a structure within cells which consists of DNA and protein.

Chromatid: one arm of one chromosome. The two chromatids of one chromosome have identical genetic information.

Centromere: the connecting point between the two chromatids of a chromosome. Chromatids separate at this point during mitosis.

Homologous Chromosomes: pairs of chromosomes which code for the same traits, one from each parent.

Gene: a portion of a chromosome that codes for a trait.

THE STAGES OF MITOSIS

Interphase: The time between mitotic cell divisions. DNA is unwrapped into long strands in such a manner that chromosomes are not evident.

Prophase: DNA condenses into chromosomes. Chromosomes attach to spindle fibers and migrate toward the center of the cell.

Metaphase: Each chromosome splits at the centromere. Chromatids are separated.

Anaphase: Chromatids migrate toward opposite sides of the cell.

Telophase: Two cells are created from the one original. Each cell has the full number of chromosomes, but each chromosome has just one arm (chromatid). The other arm will be replicated during Interphase.

CHROMOSOME MODEL DIRECTIONS

This is a model which shows the structure of chromosomes. In order to study this model, begin on the bottom left hand corner, where you will find very small two-sided structures which represent chromosomes. There are 46 such structures in a human body cell. The purpose of this model is to show you the probable make-up of a chromosome. We know that chromosomes are composed of protein and DNA (the molecule of heredity). The exact manner in which DNA is arranged in the chromosome is not known with certainty. However, this represents the currently accepted hypothesis.

In order to observe the chromosome in an enlarged way, proceed from the bottom of the diagram toward the top on the left hand side. Notice that as you proceed, you find larger and larger chromosomes, and as you observe one of these larger examples, you should find that it consists of two sides connected at one point. This connecting point, which is at the center on this model, is called the centromere. Each arm of the chromosome is called a chromatid. Thus our chromosome consists of two chromatids connected at the centromere.

On one chromosome, an individual arm, or chromatid, contains DNA which has genes coding for certain traits. On the same chromosome, the other chromatid has exactly the same DNA with exactly the same genes. Thus, you can see that each two armed chromosome consists of two full sets of DNA, coding for certain traits.

The DNA is arranged in this way so during the process of mitosis, equal and exactly the same amount of DNA can be passed to two new cells.

The current hypothesis is that DNA is very tightly coiled in the chromatid. Basically, there are at least two levels of coiling. This can be observed by looking at the chromosome in the upper left hand corner. Notice that each arm of the chromosome is represented now by a coil. Now proceed toward the right and we will dissect one of these coils. Notice on the right hand side of the diagram that there is a ladder that represents the DNA double helix. Observe how this is tightly wrapped to form a coil in one chromatid. It is believed that each chromatid may simply be one long strand of DNA.

BASIC INHERITANCE

The features that an individual possesses are due, in great part, to the genes that have been inherited from parents. The study of patterns of inheritance is called genetics.

In the study of genetics certain terms are frequently used. The following are some of the most common terms and their definitions:

Gene: a region of a chromosome that can be identified as having a role in the development of a trait. (A more precise definition based on the function of the genetic material, DNA, will be given later.)

Homologous chromosomes: members of pairs of chromosomes which are identical in shape and size.

Alleles: alternate forms of genes at specific sites on homologous chromosomes.

Dominant allele: the allele of a pair which is expressed while the other is hidden or repressed.

Recessive allele: the allele which is not expressed.

Homozygous: having pairs of genes present at the same location on homologous chromosomes which are identical.

Heterogygous: having pairs of genes present at the same location on homologous chromosomes which are alleles.

Phenotype: an observable trait.

Genotype: sets of genes considered the hereditary cause of a phenotype.

In humans, patterns of inheritance are based on the fact that an individual receives a set of chromosomes (23) from each parent. The resulting 46 chromosome complement consists of 22 pairs of homologous autosomes and two sex chromosomes. For a given pair of homologous chromosomes, genes coding for the same traits will be found. The manner in which these genes code for those traits, however, differ or be the same.

The following example will help to illustrate simple inheritance in action.

Erythroblastosis fetalis (Rh baby) is a condition that may result if a woman who has an Rh negative genotype mates with a man who has an Rh positive genotype. If an Rh negative woman is pregnant with an Rh positive baby there will be some mixing of the baby's and the mother's blood at the time of birth. Following this mixing of the blood, the mother's body will synthesize anti-Rh antibodies. Such antibodies will attack and destroy Rh positive blood cells. A first Rh positive baby will not be affected, but in subsequent pregnancies there will be a danger of destruction of red blood cells in an infant following the mixing of bloods at birth. Such a damaging situation can be prevented if it is known that the mother is Rh negative before she has any children. Thus an understanding of the inheritance of the Rh factor is important.

The Rh blood factor (Rh positive) is controlled by a dominant gene, while the absence of the Rh factor (Rh negative) is controlled by a recessive gene. The following are the possible genotypes and phenotypes for Rh:

Genotype	Descriptive Name of Genotype	Phenotype
++	Homozygous Dominant	Rh positive
+–	Heterozygous	Rh positive
––	Homozygous Recessive	Rh –

Suppose that a man who is heterozygous Rh positive marries a woman who is Rh negative. What are their chances of having an Rh baby?

During the production of sperm (meiosis) the man's 46 chromosomes would separate into two sets of 23 each. One set would have the chromosomes with the Rh positive allele and the other set would have the chromosome with the Rh negative allele. Thus, the man (because he is heterozygous) can produce two types of sperm with respect to the Rh gene.

The woman's chromosomes also separate during meiosis into two sets of 23. In her case (homozygous recessive) each set of 23 chromosomes has the same type of Rh gene (negative).

We can illustrate the situation by constructing what is called a punnet square:

Woman's Genes

Man's Genes	–	–
+		
–		

Now if we combine the Rh genes from the man and the woman in all possible ways we can determine the chances of an Rh negative offspring.

Woman's Genes

Man's Genes	–	–
+	+ –	+ –
–	– –	– –

Notice that 1/2 the boxes have a heterozygous genotype and 1/2 have a homozygous recessive genotype. The chances are 50% that the baby will be Rh positive (heterozygous genotype) and 50% that the baby will be Rh negative (homozygous recessive genotype).

Let's consider another example: Suppose a heterozygous man marries a heterozygous woman. What are the chances of an Rh negative baby?

Woman's Genes

Man's Genes	+	−
+	+ +	+ −
−	+ −	− −

As can be seen, the chances are 1/4 for a homozygous dominant individual, 2/4 for a heterozygous individual, and 1/4 for a homozygous recessive individual. The homozygous dominant and the heterozygous would be Rh positive (3/4 chance) and the homozygous recessive would be Rh negative (1/4 chance).

One last example: Suppose an Rh positive male (homozygous dominant) marries an Rh positive female (heterozygous). What are the chances of an Rh negative baby?

Woman's Genes

Man's Genes	+	−
+	+ +	+ −
+	+ +	+ −

The chances are 1/2 for a homozygous dominant genotype and 1/2 for a heterozygous genotype. There is no chance for an Rh negative phenotype.

Some Patterns of Inheritance in Humans

In the basic inheritance handout you were exposed to the general principles involved in the transfer of genetic traits from one generation to the next. The present handout presents a number of human traits that are inherited in simple ways. As you work through the handout, determine your phenotype and your genotype (if possible; you may have to determine your parents' traits in order to get genotype) for each trait.

Human Traits

1. Bent Little Finger

A dominant gene (B) causes the last joint of the little finger to bend inward toward the fourth (ring) finger. Lay both hands flat on the table, relax the muscles and note whether you have a bent or a straight little finger.

What is your phenotype? (Circle.)   Bent   Straight

What is your genotype?   BB   Bb   bb

2. Attached Ear Lobes

In most people the earlobes hang freely, but if a person is homozygous recessive (ee), the earlobes attach directly to the head and do not hang freely. You may wish to compare earlobes with other individuals in order to determine your phenotype.

What is your phenotype?   Attached Earlobes   Unattached Earlobes

What is your genotype?   Homozygous Dominant   Heterozygous   Homozygous Recessive

3. Tongue Rolling

A dominant gene (R) enables some people to roll their tongues into a distinct U-shape.

Your phenotype?   Tongue Roller   Non Roller

Your genotype?   RR   Rr   rr   Can't tell.

4. Thumb Placement

Interlock your fingers. Positioning the left thumb on top of the right one is due to a dominant gene (P). Placing the right thumb over the left one is due to a recessive gene. Do this quickly without conscious effort.

Your phenotype?   Left Over Right   Right Over Left

Your genotype?   PP   Pp   pp

5. PTC Tasting

Your instructor will provide you with a piece of paper treated with Phenylthiocarbamide (PTC). Place this in your mouth. If you detect no taste, chew for about a minute. If you do not detect a very bitter taste you are a non-taster (homozygous recessive).

Your phenotype?   Taster   Non-taster

Your genotype?   Homozygous Dominant   Heterozygous   Homozygous Recessive

6. Second (index) finger shorter than fourth (ring) finger

Place your hand on a flat surface and note whether the index finger is longer or shorter than the ring finger. Short index finger results from the action of a sex-influenced gene which is dominant in males and recessive in females.

	Index shorter		Index larger	
Your phenotype?				
Your genotype?	Homozygous Dominant	Heterozygous	Homozygous Recessive	Can't Tell

7. Blood Groups

In the ABO blood group there are 3 possible genes and 4 possible phenotypes. Each person inherits a pair of genes. The O gene is recessive, while the A and B genes are co-dominant. The following table illustrates possible genotypes and phenotypes:

Genotype	Phenotype (Blood Type)
AA	Type A
AO	Type A
BB	Type B.
BO	Type B
AB	Type AB
OO	Type O

The instructor will assist you in determining your blood type.

Your phenotype? A B AB O

Your genotype? AA AO BB BO AB OO Can't tell

8. Sex-linked traits

Some genes are carried on the X chromosome. Such genes are sex-linked (or X-linked). A female will get a pair of genes for X-linked traits because females have two X chromosomes. Males, however, will only get one of each type of X gene because males have a Y chromosome instead of a second X.

If a male inherits a recessive X-linked gene it will always be expressed, because there is no possibility of a dominant gene being present to mask its expression.

Example: Hemophilia is an inherited genetic disease in which the blood does not clot properly in an affected individual (h). A carrier female (Hh) mates with a normal male (H). If the couple has a son, what are the chances that he will have hemophilia?

The punnet square would look like this:

		Man	
		H	No gene on Y
Woman	H	HH	H
	h	Hh	h

Note the absence of a gene in the male because a Y chromosome is present rather than an X.

In such a situation the couple has a 50% chance of producing a boy (as always). If a boy is born there is a 50% chance that he will have the hemophilia gene and hence express that trait.

Problems - Complete the following.

1. A carrier for tongue rolling mates with a non-roller. What is the probability that they will produce an offspring who is a non-roller?

2. A person who is homozygous dominant for PTC tasting mates with a person who cannot taste the chemical. What is the probability that they will have a child who will taste PTC?

3. Four brothers and sisters have the following blood types: A, B, AB, O. What are the genotypes of their parents?

4. A woman who is a carrier for hemophilia mates with a normal male. What is the probability of producing a daughter with hemophilia? What is the probability of producing a daughter who will be a carrier?

EVOLUTION

1. For any given species two problems exist. The first problem is one of immediate fitness. Members of a species must have suitable characteristics for finding food in their environment, and for finding shelter, as well as for avoiding predators. The second problem is one of long term flexibility. Environments have always changed with time. As environmental changes occur, those populations with genetic flexibility may evolve and survive, while those populations which are highly specialized may become extinct.

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2. Evolution simply means change. Change is constantly occuring. Our earth has gone through innumerable changes since it originated about 4.6 billion years ago. Life on earth has been in a state of flux for at least 3.8 billion years.

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3. Organic Evolution is that aspect of change that deals with living things. From a biological standpoint organic evolution can be thought of as a change in the genetic makeup of a population over time.

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4. Ideas about evolution were formulated over a long period of time, and involved the contributions of many people. In the mid 1800's, however, two people, Charles Darwin and Alfred Wallace, brought various ideas and observations together and expressed them in a clearly stated Theory of Evolution. The publication of the book, On the Origin of the Species, by Darwin in 1859 had a revolutionizing effect on biology that has retained its importance to this day.

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5. The major ideas expressed by Darwin and Wallace are summarized in the following observations and conclusions:

Observation 1

All organisms have a high reproductive capacity. (A population of organisms with an unlimited food supply and without being subject to predation, could quickly fill the entire earth.)

Observation 2

The food supply, as well as the supply of other resources, for any population of organisms is limited. The growth rate of the population tends to outrun the growth rate of the food supply.

Conclusion 1

There must be a continual struggle for existence among organisms of the same kind.

Observation 3

All organisms show heritable variations. No two individuals in a species are exactly alike.

Observation 4

Some variations are more favorable to existence in a given environment than others.

Conclusion 2

Those organisms possessing favorable variations will be better able to survive in a given environment than those that possess unfavorable variations.

Thus each successive generation will be better adapted to the environment.

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6. Darwin used the term natural selection in referring to the greater survival, and consequently greater production of offspring, by those individuals with favorable variations.

Natural selection can be thought of as a differential reproduction in which the fitter members of a species get more of their genes into the next generation. Unfit individuals often die before reproducing and thus are represented to a lesser degree in subsequent generations.

In an environment that is fairly constant, natural selection often acts to preserve the status quo within a species. In an environment that is changing, however, natural selection often may act in a directional way leading to an increase in individuals that possess a characteristic favorable in the new environment.

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7. Speciation (the development of a new species) may occur if a population becomes separated into two or more geographically isolated groups. Such geographical splitting of a population may occur following the formation of mountain ranges or islands or rivers, or in a number of other ways.

Geographically isolated populations may be subjected to different environmental conditions that result in natural selection operating in quite different ways in the isolated populations. Over a sufficiently long period of time, evolution might lead to a divergence of characteristics between the isolated populations. If the changes that occur are great enough, eventually the two populations, that originally were one, may be incapable of interbreeding. Such populations incapable of interbreeding must be considered to be separate species.

Speciation may occur in ways other than through the development of geographic isolation. Sudden changes in the genetic material may lead to instant reproductive isolation. Such sudden changes appear to have occurred quite often in plants, and have usually involved a sudden increase in chromosome number, such as a doubling or tripling of the original chromosome number (polyploidy). If polyploidy occurs in at least two individuals, crossbreeding of these individuals may lead to the establishment of a reproductively isolated population.

ECOLOGY

Ecology is the study of the relationships between organisms and their environment.

The environment contains both physical and biotic components. Major physical aspects of the environment include minerals, light, temperature, moisture, and pH. Living forms make up the biotic portion of the environment.

A person who studies aspects of the relationships of organisms and their environment is called an Ecologist. An ecologist may concentrate on one or more of the following levels of organization: Organism, Population, Community, Ecosystem, Biome, Ecosphere.

A population is a group of individuals capable of interbreeding (members of a species within a particular geographic area).

A community is a group of populations living in the same general area characterized by interdependent relationships.

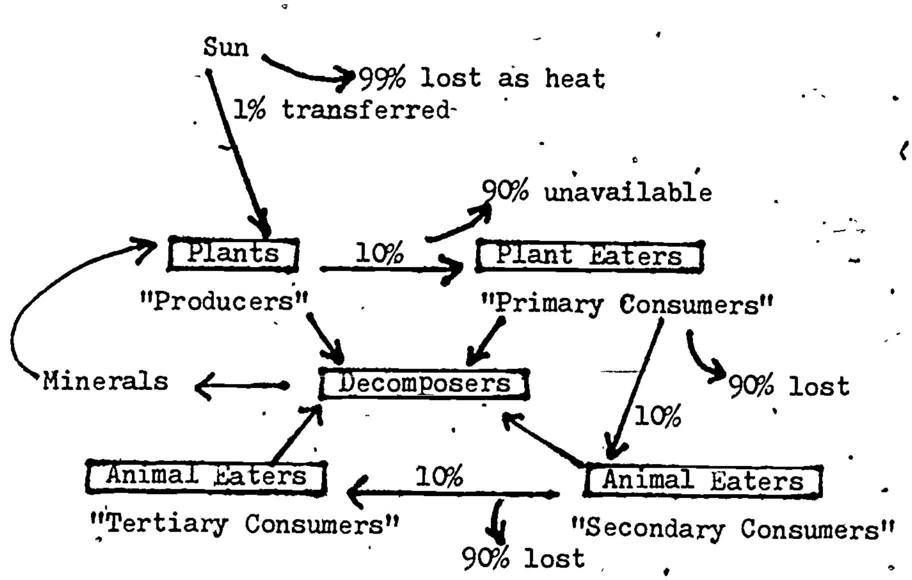
An ecosystem is a community plus its physical environment treated as a functional unit. Ecosystems are characterized by a cyclic exchange of materials and are theoretically self-sufficient units. The only outside requirement of a balanced ecosystem is an input of energy (from the sun, either directly or indirectly).

Biomes are big areas on earth (large ecosystems). Common terrestrial biomes include the Temperate Deciduous Forest, the Tropical Forest, the Taiga, Grasslands, Chaparral, Desert, and Tundra.

The earth itself is really one giant ecosystem which we call the Ecosphere.

Ecologists most often concentrate their studies at the level of the Ecosystem because this level represents the functional ecological unit.

The flow of matter within an ecosystem, and energy through an ecosystem is illustrated in the following diagram: (Arrows denote direction of energy and matter flow.)



Levels within the ecosystem are called "Trophic Levels". The system begins with sunlight being absorbed by the plants. Less than 1% of the sunlight entering the earth's atmosphere is used by plants. The bulk of the light is converted to heat which warms the atmosphere. Plants and other Autotrophs represent the "Producer" Trophic Level.

Producers are eaten by members of the "Primary Consumer" Trophic Level. Only 10% of the energy potentially available at the Producer Level is transferred to the Primary Consumer Level. The rest of the energy is lost as waste heat. In general the efficiency of energy transfer from one trophic level to the next is about 10% .

Primary Consumers are eaten by Secondary Consumers. For example, coyotes eat rabbits. Again our efficiency of energy transfer is about 10%. Secondary Consumers may be eaten by Tertiary Consumers, and occasionally even higher level consumers are found in an ecosystem.

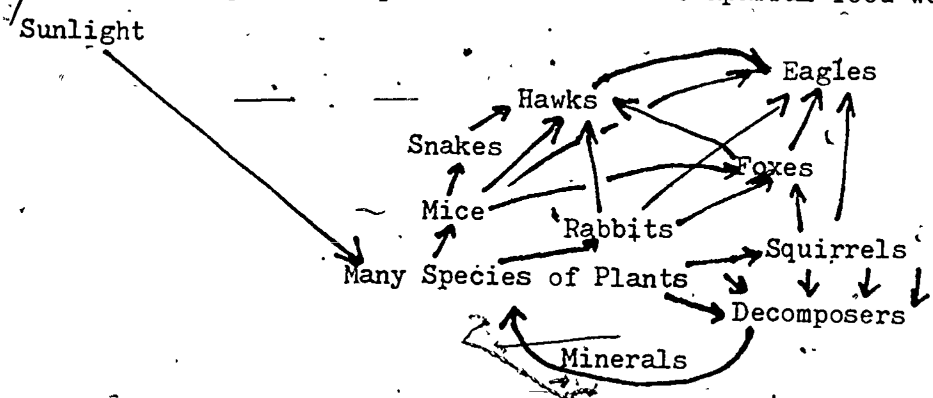
A vital role is played by the "Decomposer" Trophic Level which consists of Bacteria, Fungi, and related organisms of decay. These decomposers break down complex molecules from dead plants and animals and animal wastes into simple minerals. Matter is then recycled as these minerals are taken up by members of the Producer Trophic Level.

Each particular member of an ecosystem plays a particular role in the total system. The sum total of all aspects of an organism's role in the ecosystem is referred to as the organism's "ecological niche".

A complex series of links exists among the organisms within a single ecosystem. An expression that shows just a few of the systems' interrelationships is a <u>food chain</u>. For example:

Sunlight   Rabbitbush   Rabbit   Coyote

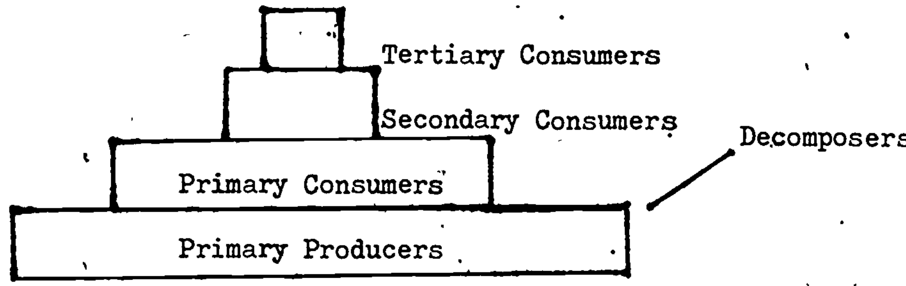
A more complete expression of the interrlationships within an ecosystem is a <u>food web</u>. The following is a simplified California Chaparral food web:



Most food webs are fairly complex, although some, such as the tundra foodweb, are simple. People, through their activities sometimes reduce the number of links in a food web by eliminating species. For example, the Grizzly Bear would be a part of the previous web had it not been eliminated by people.

A generalization that is often true is that the more complex the food web is, the more stable it is. Often simple food webs are relatively unstable or more susceptible to disruption. The Tundra is thus a fragile ecosystem because it has a relatively simple food web. People may make ecosystems more vulnerable to change—when species are eliminated or food web links are disrupted.

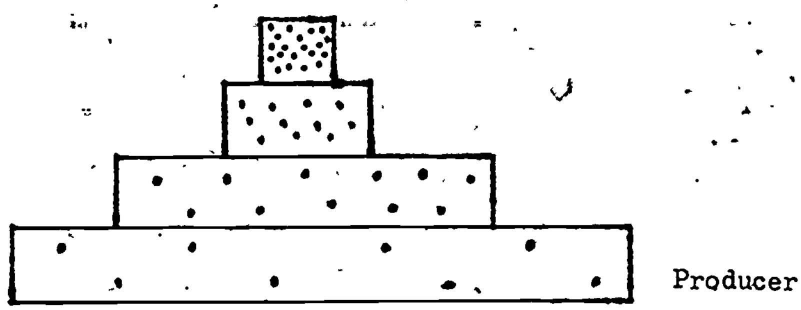
Due to the energy inefficiency that occurs from one trophic level to the next we find less biomass, less energy and fewer individuals on successively higher trophic levels. Such a relationship can be expressed as a pyramid (of Biomass, Energy, or Numbers).



Although energy, biomass, and numbers generally decrease from lower to upper trophic levels, some toxic substances may do just the opposite. The process of biological magnification may occur for fat soluble substances such as DDT, PCB's, organic mercury, and some radioactive substances. In such cases, the concentrations of the toxic substances are higher in tissues of upper trophic level organisms.

The following diagram illustrates what happens:

The size of the square represents the total biomass at each trophic level. The individual dots represent molecules of a toxic substance.



As one can see, little of the toxic substance is lost during transfers from one trophic level to the next, but much of the biomass is lost. The result is a higher concentration at higher trophic levels.

For example, in a freshwater ecosystem the following DDT concentrations were observed:

DDT in parts/million

Plankton →	Minnow →	Large Fish →	Osprey (A bird of prey)
.04	.23	2.07	13.80

Such high concentrations of DDT affect eggshell production in birds and represents a serious threat to the survival of several species.

It is especially important that we minimize the release of substances that exhibit biological magnification into our environment. Such compounds not only threaten wildlife, but may also have detrimental effects to humans.

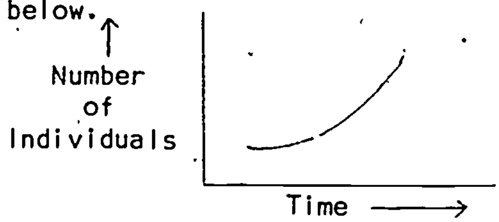
POPULATION AND ECOSYSTEM DYNAMICS

For any species there are environmental requirements which will affect both its abundance and its distribution. Such features are called limiting factors.

A limiting factor may be a density independent one such as temperature or pH or a density dependent factor such as disease, food supply, or number of predators. Density dependent factors exert a stronger effect on a population's continued growth as it increases in numbers.

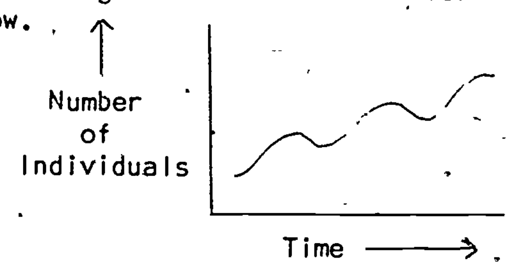
Density independent factors exert their effects regardless of population size.

Populations exhibit different patterns of growth depending on the species in question as well as environmental conditions. In some cases, such as an insect invasion or an algae bloom, population growth can be very rapid. Such a situation is graphed below.



The curve that results when such a rapid burst of growth occurs is called a J curve.

In many established populations the numbers of individuals are fairly constant, generation after generation. A curve for a fairly stable population is illustrated below.



Such a curve, where the population size is fairly constant, is called an S curve. In this situation, limiting factors in the environment function to keep the population from continuing to increase in numbers. The limiting factors thus provide environmental resistance to continued growth. The size of the population that is fairly constantly maintained, generation after generation, is called the carrying capacity.

The carrying capacity is often determined by a number of density dependent factors which may include food supply, shelter, disease, number of predators, or number of prey.

Many populations can be expected to exhibit an S curve type of population pattern generation after generation. In some cases, however, changes may occur in an ecosystem that will lead to the ultimate disappearance of certain species. Such events often occur during the process of ecological succession.

In ecological succession environmental changes occur in such a way that one type of ecosystem may replace another. Often a series of ecosystem replacements may occur. For example, one possible sequence is illustrated below.

Freshwater Lake   Marsh   Bog   Meadow   Forest

Ecological succession may eventually lead to an ecosystem which is very stable and which resists change. Such a stable ecosystem would be called the climax stage or climax community.

Trends that often occur during ecological succession are listed below:

1. The total biomass increases.
2. Net productivity initially increases, but during later stages of succession it decreases.
3. There is a general increase in organism size, organism lifetime, and complexity of life cycles.
4. There is an increase in species numbers and thus an increase in foodweb complexity.
5. Usually ecosystems become more stable as they mature.

NATURE OBSERVATION

The natural world offers experiences that are unavailable in urban areas. Because many of us have grown up in the city these experiences may be new and the ability to appreciate them may need to be acquired. A sharpening of the senses will occur as one learns to hear and recognize new sounds, to explore the variety of tactile stimuli, and to analyze unusual, but generally pleasing odors.

A place to begin nature observations is usually fairly close. In the city, a large park will have much to offer. The seashore and related areas such as saltmarshes are excellent for nature study, especially during the fall and winter when there are fewer visitors. It is always a rewarding experience to visit undeveloped areas within state or national parks.

Listening to Nature

Sound is a primary means of communication among animals. With practice you will learn to recognize the calls of several species of birds. Insect sounds should also become recognizable.

If possible, it is worthwhile to study sounds both during the day and at night because this will allow you to gain a greater feeling for the animals present in your study area. Birds call mainly in the daytime, while at night frogs, toads and some mammals are vociferous.

In order to learn an animal by sound some repetition may be necessary. Listen to the recorded sounds of birds for example before you go into the field. On your field trip see if you recognize calls that you previously heard. Take your tape recorder, with the pre-recorded tape provided by the instructor, into the field with you. You can play back the tape to confirm the sound of a particular species. In addition, if you broadcast a particular taped call, you may get a response from a bird in the field. Such a response should confirm your identification and will allow you to hear additional calls of the bird.

Since sound serves as a primary means of communication among animals, there must be a sound dialect for any particular species. If you find a particular species of animal common and interesting, you may wish to study its different sounds or vocalizations. For example, if you observe an Anna's hummingbird, you should detect an "announcement sound" as the bird sits on its territorial perch. The announcement sound has been described as a recurring sequence of raspy triplets, a drawn-out creak, and two staccato chirps. The announcement sound lets other hummingbirds know that a particular territory is occupied. If a hummingbird intruder enters the territory, you may hear a chatter call. The chatter call threatens attack. If the hummingbird is courting you may hear single high pitched chirps or peeps. Such sounds are not vocalizations but rather are produced by the wings in a very steep aerial dive. As you observe birds, or other animals, you will begin to detect different sounds being given by one individual. You may wish to interpret the meaning of such sounds.

The nature of a sound may be a key to its meaning. For example, many species of songbirds will make a chattering, raucous sound when a predator such as a fox or cat is nearby. Such a sound is easy to locate and serves to let other birds know where the danger is. Sometimes such calls lead to mobbing with many individuals ganging up to chase the predator away. Another sound made by songbirds is a high pitched, difficult to locate "cheep" sound. Such an "alarm call" is given when a predator such as a hawk is in the area. When this call is given the other birds hide and fall silent. It is usually easy for humans to detect the mobbing call, but not the alarm call.

Depending on the season and the animal, sounds may be of differing characters. For example, many male birds sing in the springtime to establish territories. "Songs" are usually complex and melodious. Birds generally call rather than sing during the non-breeding season. "Calls" are shorter, simpler sounds, and usually not very musical. Animals other than birds also show this seasonal variation. Most male frogs, for example, establish spring breeding choruses where species-specific breeding calls are given to attract females. During the non-breeding season it is often possible to hear quieter and more variable non-breeding season frog calls.

As you learn to interpret wild sounds your appreciation of nature should increase. Try to learn several species by sound and at the same time see if you can determine meanings of different types of signals (e.g., threat, attraction, species recognition, etc.)

The Smells of Nature

Odor plays a major role in the lives of many plants and animals. A night-blooming flower may attract a moth with its sweet scent. A female woodrat may communicate to a male woodrat that she is sexually receptive by releasing an odiferous chemical. A coyote may mark his territory with urine that carries his particular scent. A skunk may spray a young badger that was just too curious.

The smells of nature are a delight that is never found in the city. The rich musky smell of humus in the oak woodland, the intensely sweet fragrance of a field of clover, the wild, primitive scent of the freshwater pond are joys which most of us experience all too infrequently.

As you explore your wild areas try to note as many different smells as possible. What are the possible biological functions, if any, of these smells? For example, one function of sweet-smelling nectar in a flower is to attract pollinators. Discuss possible functions with your classmates and with your instructor.

The Textures of Nature

Reach down, pick up some soil and rub it between your fingers. The texture of the soil tells you something about the types of plants that may be found in an area. A coarse gravelly soil may only support very hardy plants such as those found in the chaparral. A richer and more finely textured soil may support oak trees. Soil occurs as many types, but with practice and help from your instructor, you should be able to tell whether a soil is primarily clay, silt, or sand.

As you study soils, relate them to the plants with which you find them associated. To a certain ~~extent the~~ soil type determines the vegetation type in a given area. For example, chaparral is usually found growing in soil that contains a lot of gravel, while a grassland community often grows on a heavy clay soil.

The textures of plants may help in learning different plant species in a given area. In the chaparral, for example, many plants have distinctive characteristics as outlined in the following table:

Plant Species	Touch Identification Features
Chamise	Stiff cylindrical needle-like leaves
California Buckwheat	Needle-like leaves with indentation on leaf bottom
Scrub Oak	Acorns present, sharp points on leaves (usually)
Laurel Sumac	Smooth waxy leaf without serration
Sugarbush	Thick, waxy leaf

Black Sage	Coarse texture - sage smell
White Sage	Smooth, sticky texture - sage smell
Toyon	Even serrations along a long narrow leaf; mild almond odor when crushed with fingers
California Sagebrush	Narrow, long leaves, Sagebrush odor
Holly Leaf Cherry	Intense almond odor when crushed in fingers

Going on a Field Trip

When you venture into the field be sure that you are suitable clothed and suitably equipped. Wear clothes that you can allow to get a little dirty, since you will certainly be sitting, and perhaps even lying, on the ground. Denim jeans are a comfortable choice for pants. Tennis shoes are a good bet for footwear. If it is likely to be sunny a longsleeve shirt and a hat will provide protection against sunburn.

The most important piece of equipment on an extended nature walk will be a container with water. You may wish to bring materials for recording your nature observations. A compact tape recorder can be extremely helpful for saving your field experiences. A small backpack is useful for carrying all your materials. Your instructor will discuss the different types of packs, belt-bags, and shoulderbags that are available.

Field Activities Sheet

Record the following information while in the field:

1. Bird species observed. Try to describe the sound made by each different species.
2. Plant species observed. Try to describe the particular characteristics of each plant that allow you to distinguish it from other plants in the area.
3. Types of soil observed. Can you link types of vegetation (plant communities) to particular soil types? What other physical features might play a role in the type of plant community found in the given area?
4. What are some inportant values of wild natural areas? You should be able to list at least five reasons that such areas are important.

CHAPARRAL FIELD TRIP

Today you will be able to personally experience the most common plant community of the Santa Monica Mountains. You will benefit from reading the Santa Monica Mountains plant community handout (in addition to this handout) both before and after the field experience. This chaparral handout is designed to acquaint you with the common plants and animals that you will encounter on the trip.

CHAPARRAL PLANTS

Chaparral plants are adapted for survival in a Mediterranean type of environment, characterized by wet winters followed by a very long dry season. Such plants usually have thick, leathery leaves and extensive root systems. The following is a list of common plants with some descriptive information. Space has been left below descriptions for you to tape specimens to this handout.

California Buckwheat (Eriogonum fasciculatum)
Small needle like leaves. Large brittle flower clusters at tips of stems. This plant is an important bee plant due to its long blooming season.

Chamise (Adensotoma fasciculatum)
Small needle-like leaves, smaller than buckwheat leaves. Small flower clusters. This is a very common, often dominant, chaparral plant.

Hollyleaf Cherry (<u>Prunus illicifolia</u>)

Leaves are roundish, leathery, and lined with prickles. When crushed the leaves first give off an unplesant cyanide odor which quickly changes to a very plesant almond smell.

Toyon (<u>Heteromeles arbutifolia</u>)

Stiff linear leaves lined with sharp teeth. Berries are on plants during much of the year. This plant is also called Hollywood. The famous town was given the name because the surrounding hills were covered with this species.

Poison Oak (<u>Rhus diversiloba</u>)

This plant should not be handled because it causes severe skin irritations. Poison oak is found in shady and moist areas and is not common in the Chaparral.

California Sagebrush (<u>Artemisia</u> <u>californica</u>)
Aromatic odor. Soft, very narrow, linear leaves. Very common in the Coastal Sage Scrub.

White Sage (<u>Salvia</u> <u>apiana</u>)
Aromatic. Large, broad, rough leaves.

Black Sage (<u>Salvia</u> <u>mellifera</u>)
Aromatic. Narrow, rough leaves. Leaves are finely wrinkled on the upper surface. Dried flower clusters along stems are distinctive.

PLANT BIOLOGY

I know a bank where the wild thyme blows,
Where oxlips and the nodding violet grows
Quite over-canopied with luscious woodbine,
With sweet musk-roses and with eglantine.

William Shakespeare
- A Midsummer Night's Dream

Plants play a multitude of important roles on our earth. Perhaps the paramount feature of plants is their ability to do photosynthesis. Through the process of photosynthesis plants produce food and oxygen, materials which are essential for life. Plants play other roles in our lives which are extremely worthwhile. For example, plants enrich our lives by providing aesthetic beauty.

The beauty of plants can be appreciated in many ways. Many individuals enjoy plants because of plants visual appearances. Often other features of plants are overlooked, however. For example, there are many species of plants with very exciting smells or scents.

This handout will provide an introduction to several aspects of plant biology, including a discussion of scented plants, plant structure, and plant function.

Scented Plants

The following ~~is a list of plants~~ which have scented leaves. Some of these plants will be avaliable from your instructor, others from nurseries.

Leaves should be lightly rubbed to release scents.

Scented Geraniums:

(1). Peppermint Geranium (Pelargonium tomentosum)

This plant releases a delightful peppermint odor when the leaves are rubbed. In addition the large, fuzzy leaves make the plant particularly attractive.

(2). Lemon Geranium (Pelargonium crispum)

This plant has very small curled leaves. The lemon scent is so nice that one is tempted to eat the leaves.

(3). Rose Geranium (Pelargonium capitatum)

This plant produces a rose scent. Leaves have been used to make rose geranium jelly and as a basis for rose perfume.

(4). Lime Geranium (Pelargonium nervosum)

This plant has a very spicy odor and soft-textured leaves.

(5). Nutmeg Geranium (Pelargonium graveolens)

Almost smells like nutmeg.

Early in the nineteenth century there were as many as 200 varieties of scented geraniums avaliable. Great collections were assembled and played an important part in every horticultural exhibit. Today these plants are tremendously neglected, although their popularity seems to be increasing.

The scented geraniums are native to south Africa. In the wild environment the scents may play an important function in the lives of the plants. Perhaps, as you observe these different species, you will speculate concerning the roles of the various scents. Perhaps you might even become a collector and expert.

Scented Herbs:

A wide variety of herbs have interesting smells, textures and culinary uses. This is a partial list.

(1). Thyme (Thymus species)

There are several species and varieties of thyme with many different smells. Some of the more common scents include common thyme, lemon , caraway, and pineapple.

(2). Rosemary (Rosmarinus officinalis)

This plant has a strong pugnent odor.

(3). Mints (Mentha species)

There are many species including peppermint, spearmint, pineapple sage, and corsican mint.

(4). Lavender (Lavandula species)

Finely scented elegant fragrance.

(5). Others

There are many more species of herbs which are worth becoming familiar with.

Plant Structure

The instructor will discuss plant structure, and you will explore various portions of plants through the use of models. The following is a list of important terms which you should understand.

The Flower

(1). Pistil: female portion of flower
- a. Stigma: pollen lands and germinates here
- b. Style: pollen tube grows through this structure
- c. Ovary: houses ovule, within which is the egg

(2). Stamen: male portion of flower
- a. Anther: produces pollen
- b. Filament: supports anther

(3). Petals: often designed to attract pollinators

(4). Sepals: protect un-opened flower

Leaves and Stems

(1). Leaf: flattened portion of plant where most photosynthesis occurs
- a. Blade: generally wide flat area
- b. Petiole: narrow "stemlike" portion of leaf
- c. Bud: Structure next to petiole and stem

(2). Stem: support for plant parts
a. node: swollen portion of stem
b. internode: area between nodes

(3). Stem cross section
a. Xylem: transports water and minerals
b. Phloem: transports food
c. Cambium: has actively dividing cells

Roots

(1). Root Cap: area of hard dead cells which is pushed through the soil.

(2). Meristem cells: actively dividing cells

(3). Root Hairs: absorb water and minerals.

DESCRIPTIONS OF MODELS

The following brief descriptions refer to the models generated during the course of this project. A photograph of each model is included in the figures following the descriptive text. Most models are labeled in both braille and written script.

1. TEXTURED BALL AND STICK MOLECULE SET (Figures 1, 2)
   This set consists of four spheres, each representing one of four common atoms. Students can assemble models of common biological molecules by connecting the spheres with wooden and plastic bonds. Spheres have the following appearances:

Type of Atom	Size	Texture	Number of Holes (for bonds)
Hydrogen	Small	Smooth	One
Oxygen	Large	Rough (small beads)	Two
Nitrogen	Large	Rough (crushed walnut shells)	Three
Carbon	Large	Smooth	Four

   The different textures and numbers of holes for bonds allow students to easily distinguish among the spheres. Spheres were constructed with a commercial instant paper mache. Outer surfaces were painted with acrylic paints. Textures were glued on the outer surface following painting.

2. SIMPLE SUGAR SET (MONOSACCHARIDES) (Figures 3, 4)
   This set shows the general shapes of the common hexose sugars. A velcro tipped wooden bond can be manipulated to demonstrate disaccharide synthesis. 1,4 and 1,6 glucoside bonds can be formed with the model. Several glucose molecules can be connested in sequence to demonstrate polysaccharide synthesis. The hexose shapes were constructed of masonite. Wood dowels represent the bonds.

3. FAT SYNTHESIS MODEL (Figure 5)
   Raised plastic letters are used in this model so that the student may observe the structure of a Triglyceride. Atoms between glycerol and the fatty acids are manipulative (velcro attachments) so that a student may observe how dehydration synthesis and hydrolysis play a role in the building and the degradation of fat molecules.

4. PHOSPHOLIPID MODEL (Figure 6)
   Raised letters allow the student to observe the structure of a phospholipid.

5. PEPTIDE BOND MODEL (Figure 7)
   Raised letters allow the student to observe amino acid structure. Manipulative atoms (velcro attachments) allow the student to observe peptide bond formation.

6. ENZYME MODEL (Figures 8, 9)
   This three dimensional model will aid the student in understanding the relationship of shape to function in enzymes. The model is manipulative. As the substrate portions are positioned against the enzyme, they become bound together by a velcro attachment.

7. LEVELS OF PROTEIN STRUCTURE (Figure 10)
Flexible beads arranged along a wire allow the student to appreciate the levels of protein structure (primary, secondary, tertiary). The length of beads can be twisted into a helix, and the helix can be folded back on itself.

8. CELLULAR COMPONENTS (Figures 11, 12, 13)
These three dimensional models, constructed of clay, allow the student to observe general shapes of internal cellualar structures. Included in the set are models of the nucleus, endoplasmic reticulum, lysosome, mitochondrion, and Golgi complex.

9. CELL MEMBRANE (Figure 14)
This three dimensional model is constructed of clay. The components are permanently glued to a demonstration board.

10. CELLULAR RESPIRATION (Figures 15, 16)
This model allows the student to trace the major steps of cellular respiration. Three dimensional acrylic pieces (glued to an acrylic sheet) represent various components of the process.

11. MITOCHONDRION (Figure 17)
This large clay model allows the student to observe the external and internal portions of this organelle.

12. ATP (Figure 18)
A three dimensional diagram of ATP is accompanied by a raised letter summary of the ATP cycle.

13. PROTEIN SYNTHESIS (Figures 19, 20, 21)
Individual masonite pieces allow the student to work through the process of protein synthesis in a step by step manner. A nine nucleotide DNA double helix can be assembled by connecting the subunits. Individual pieces attach with velcro. A nine nucleotide mRNA can be assembled on one side of the DNA. The mRNA can then be manipulated with tRNA pieces and amino acid pieces to form a three amino acid protein.

14. LEVELS OF CHROMOSOME STRUCTURE (Figure 22)
This three dimensional model allows the student to relate the DNA molecule to the chromosome. The model presents a current hypothesis of how DNA may be packaged in chromosomes.

15. MITOSIS (Figures 23, 24)
The mechanism of mitotic division is illustrated with clay chromosomes glued to a demonstration board. One homologous chromosome is textured while the other is smooth. Additional chromosomes are available for student manipulation.

16. MEIOSIS (Figures 25, 26)
Meiotic division is represented by clay chromosomes glued to a demonstration board. One homologous chromosome is smooth, while the other is textured, so that the student can clearly observe the results of crossing over.

17. CROSSING OVER (Figures 27, 28)

Manipulative chromosomes allow the student to work through the process of crossing over. Each chromatid consists of 9 vinyl or acrylic pieces attached by celcro connectors. Pairs of chromatids are attached at a velcro centromere. A student can easily distinguish between the two chromosomes because one contains cylindrical units, while the other contains rectangular units.

18. MONOHYBRID CROSS (Figure 29)

A manipulative punnet square allows the student to work through various genetics problems. All letters are velcro backed and movable.

19. SEX LINKED TRAITS (Figure 30)

Velcro backed letters allow students to work through sex linked patterns of inheritance.

20. BULLETIN BOARD FLOW CHARTS (Figures 31, 32)

Here a simple arrangement of words in print and braille allow the student to follow a sequence of events. In the photograph the labels are taped to a cork board. In practice it would be best to attach the labels to the board with flat-headed thumbtacks. A variety of diagrams can be quickly assembled with this technique.

ACKNOWLEDGEMENTS

This project was supported by the California Community College fund for instructional improvement, under the direction of the State Chancellor's office. The written sections on carbohydrates and proteins are based on handouts developed originally by Jim Kerr and Chuck Schneebeck. Models were constructed by Paula Mckenzie Allan, Mary Allan, and Doug Allan. Ali Mesghali built the levels of chromosome structure model. The protein synthesis model is based on a design developed by Mark Hoffmann. Judy Daniels provided technical support and typed the manuscript. Material was brailled by the staff of the Sixth District PTA, San Jose, California, and by Joyce Robinowitz. Braille materials were reproduced at the Braille Institute, Los Angeles, California. Chris Schinenberger, Cathy Molini, Judy Schwartz, Maxine Hagins, and Art Marshburn provided valuable assistance during this project.

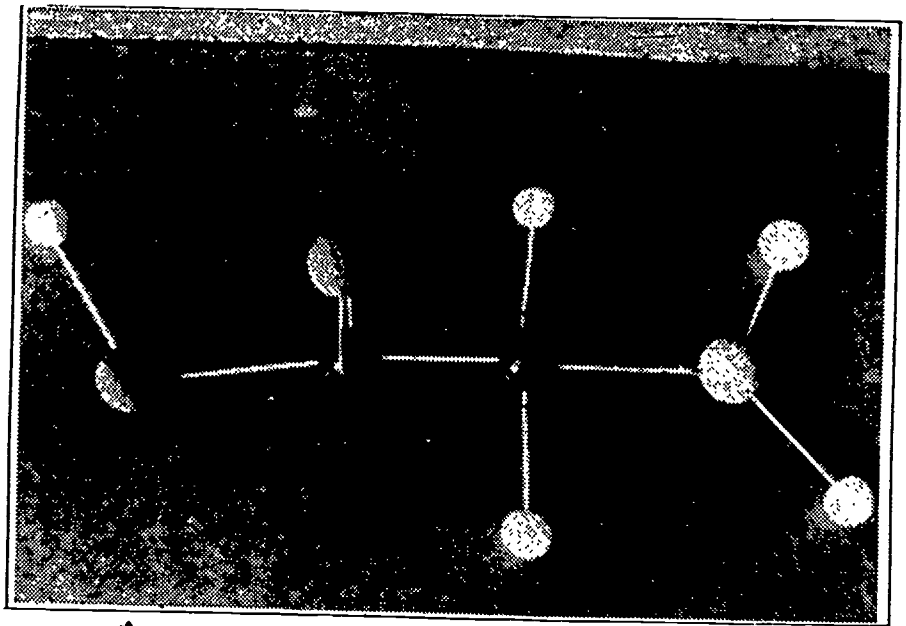


FIG. 1

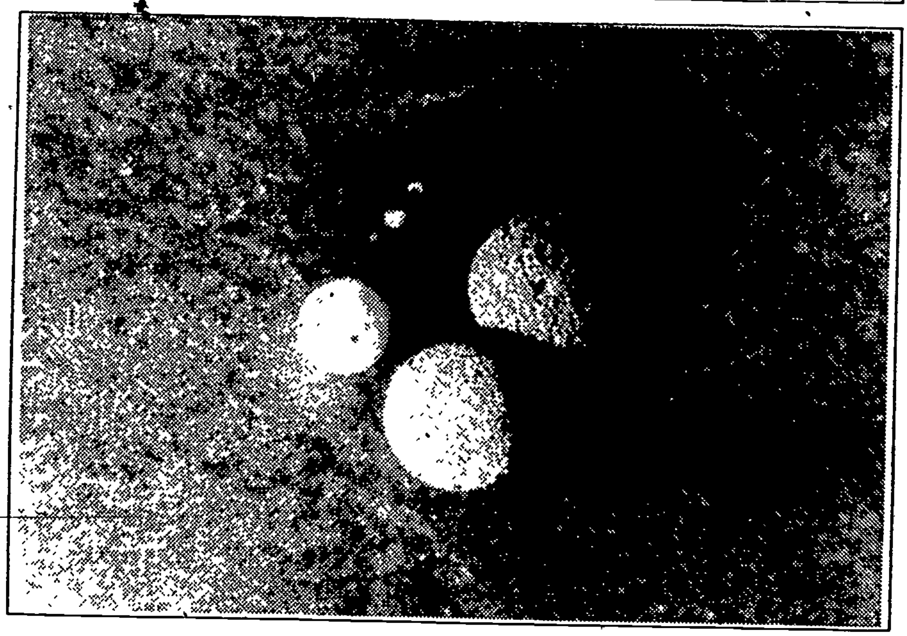


FIG. 2

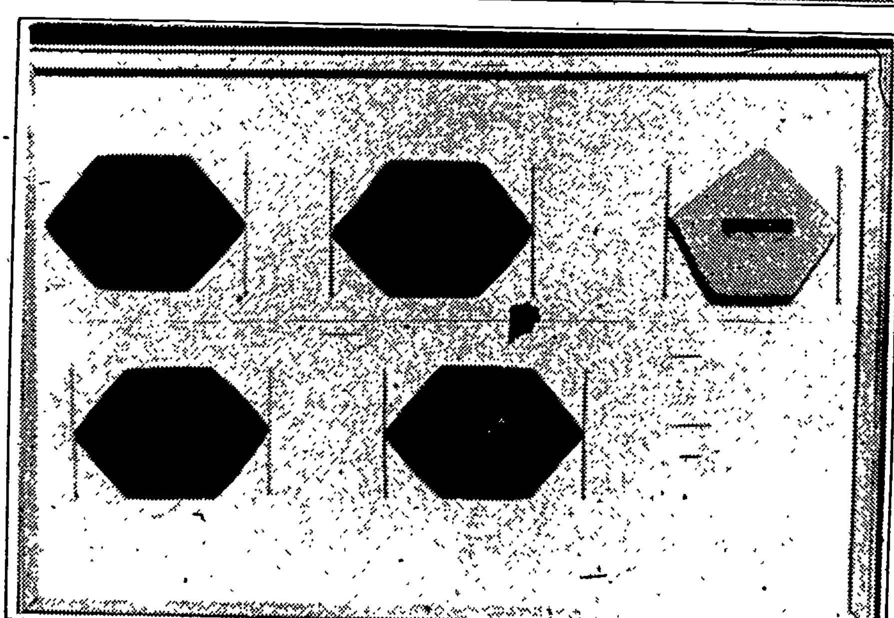


FIG. 3

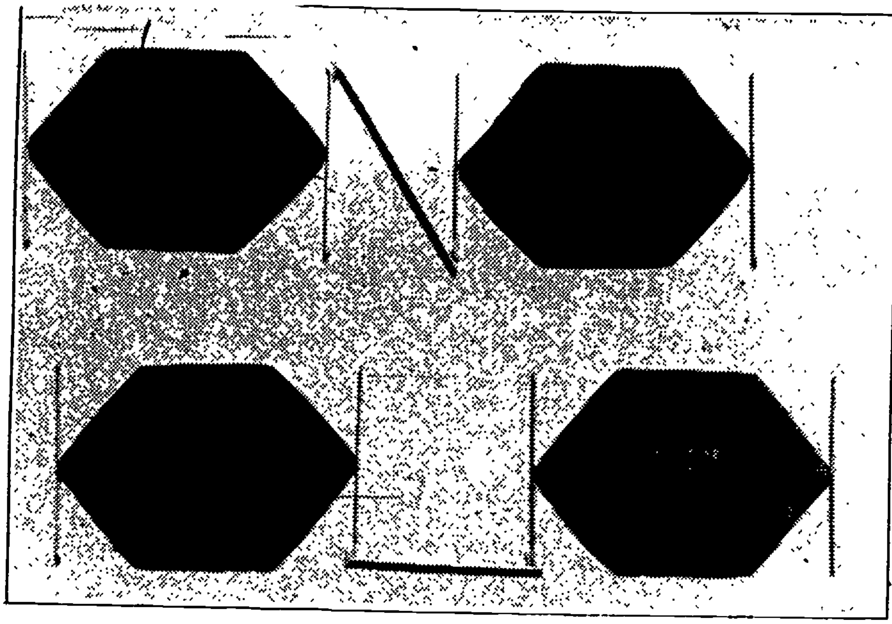


FIG. 4

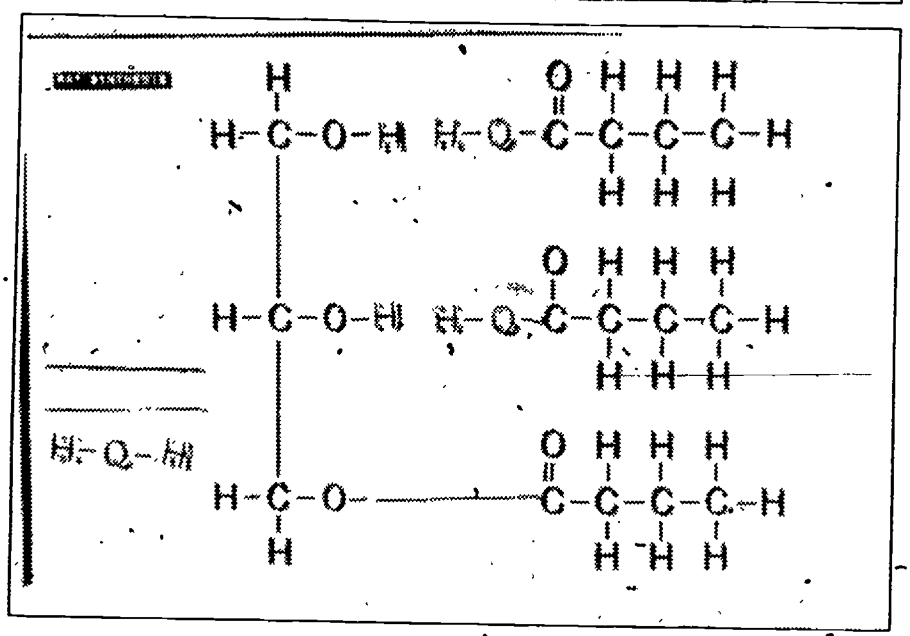


FIG. 5

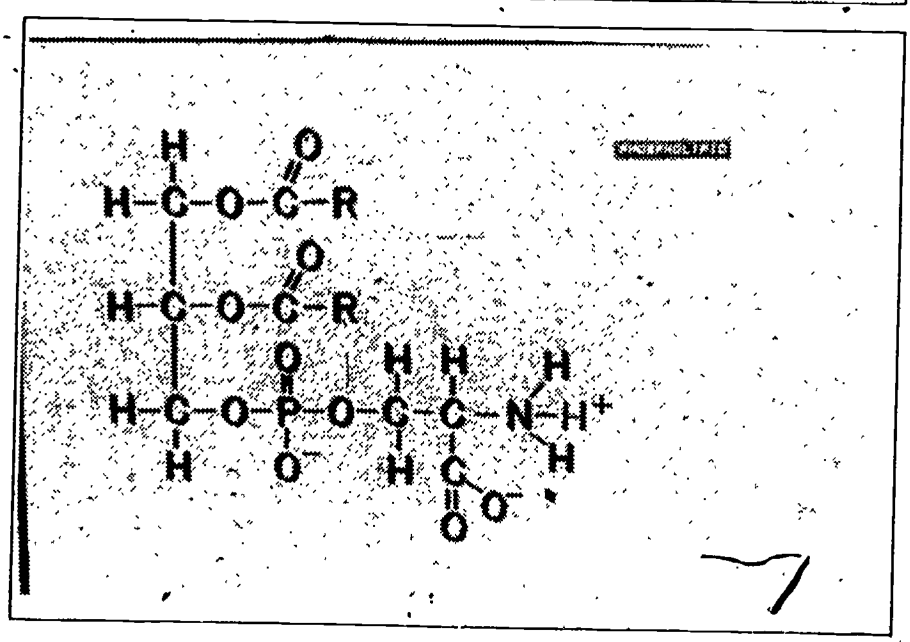


FIG. 6

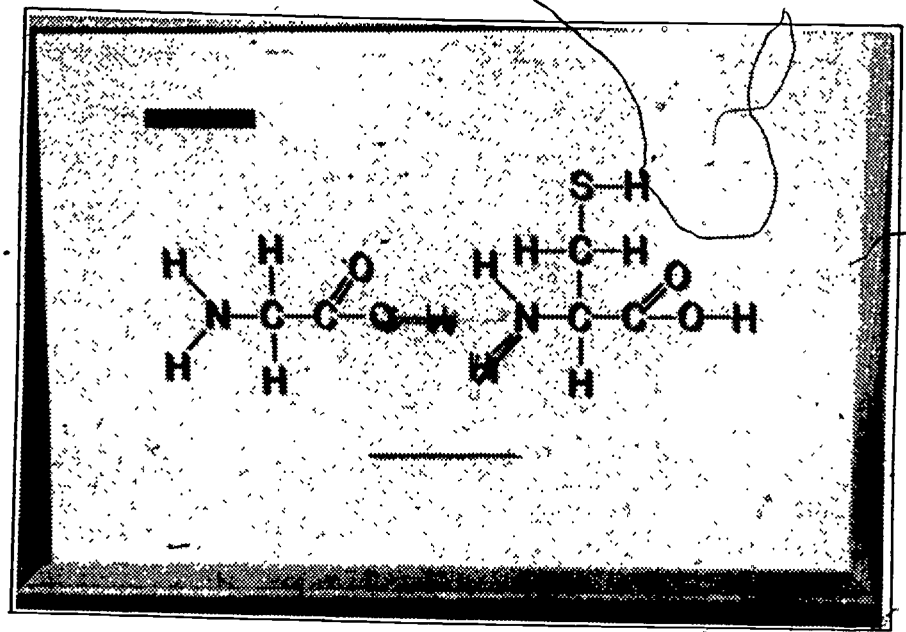


FIG. 7

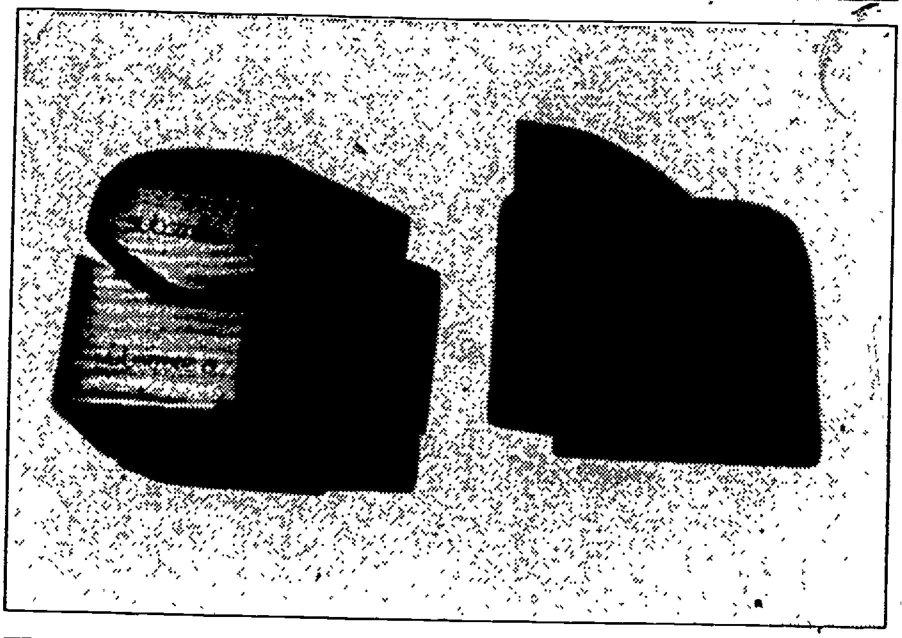


FIG. 8

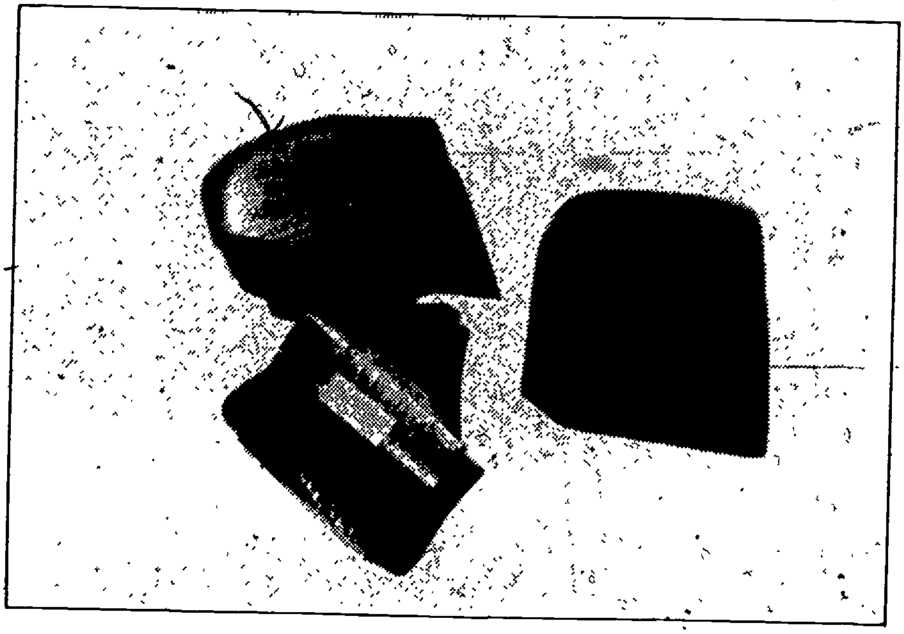


FIG. 9

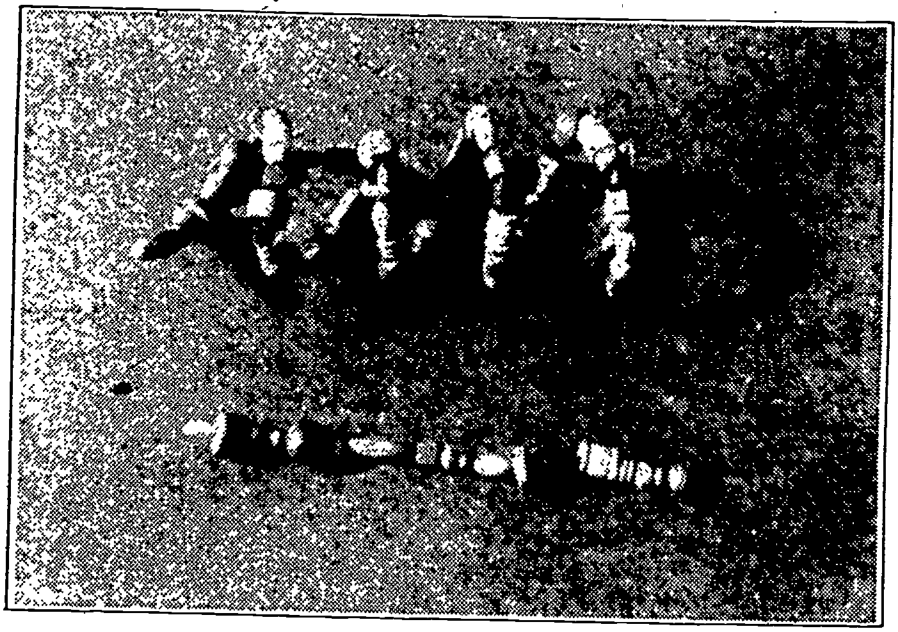


FIG. 10

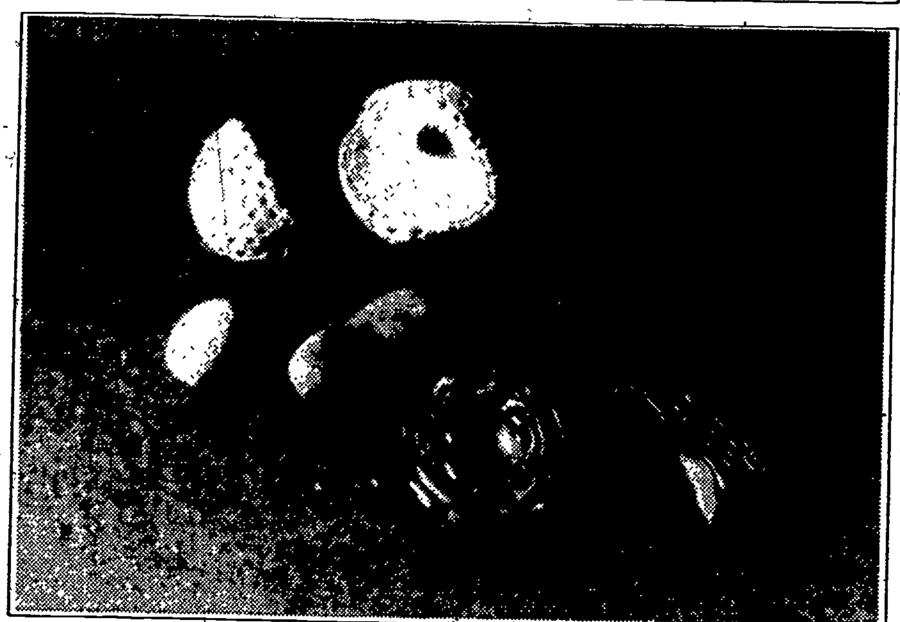


FIG. 11

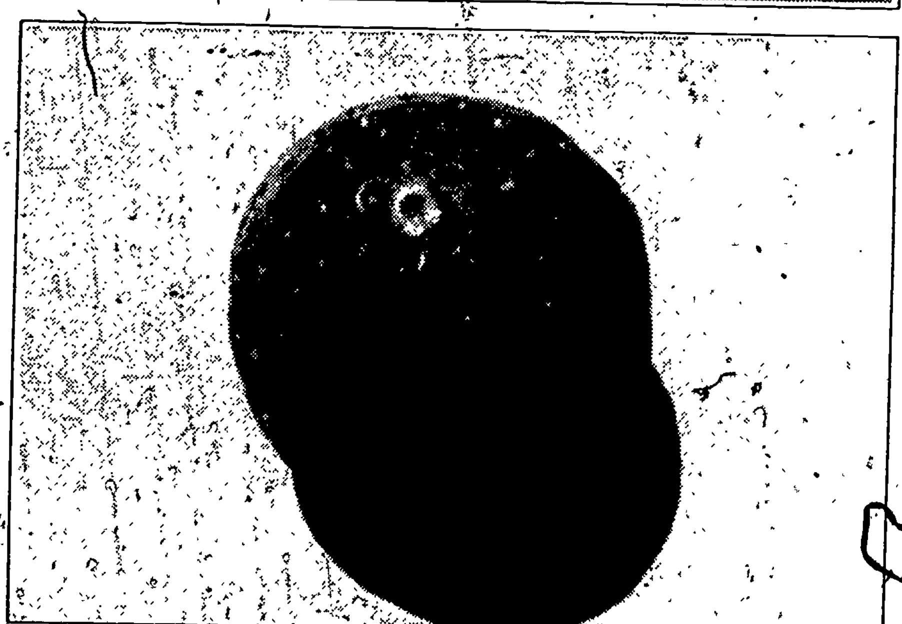


FIG. 12

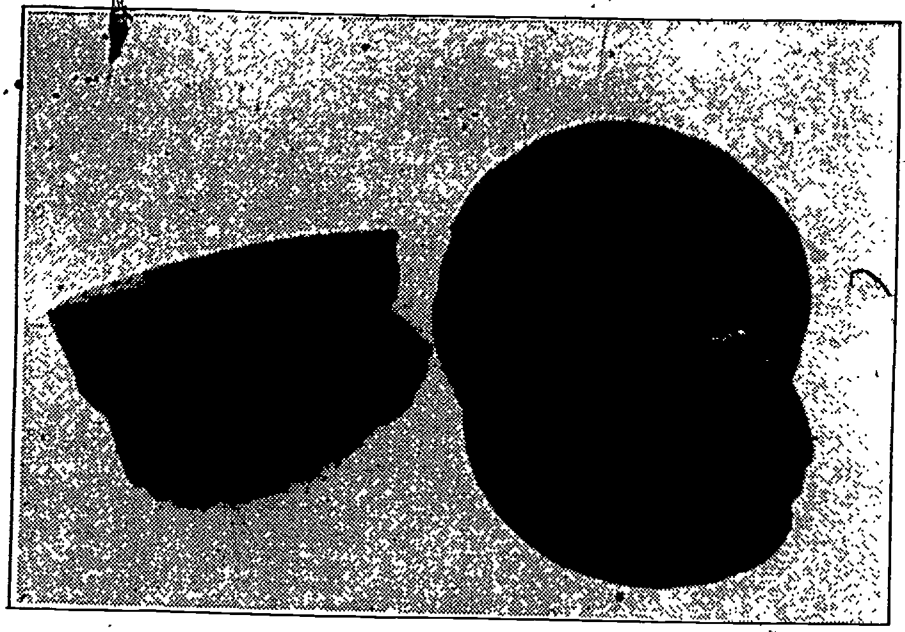


FIG. 13

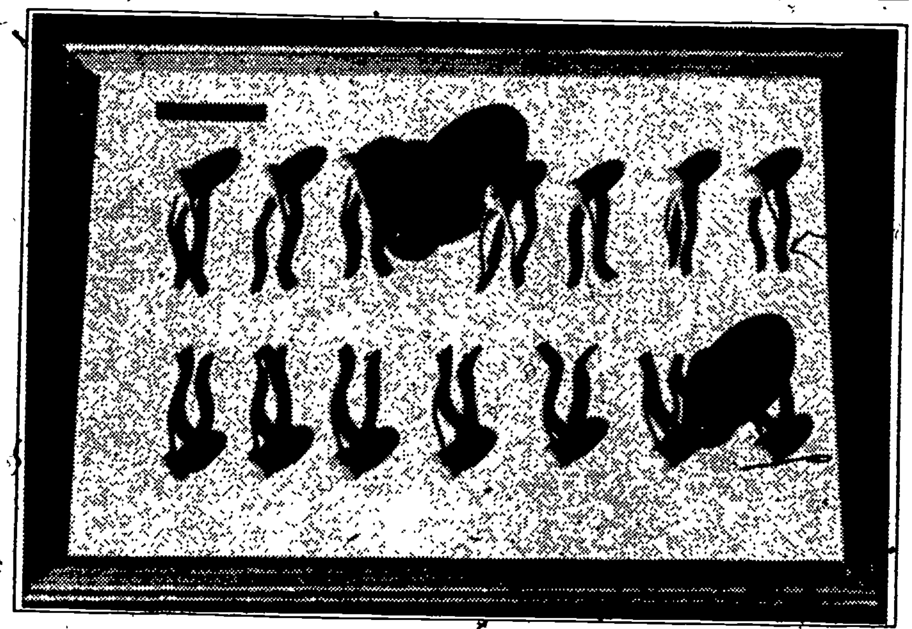


FIG. 14

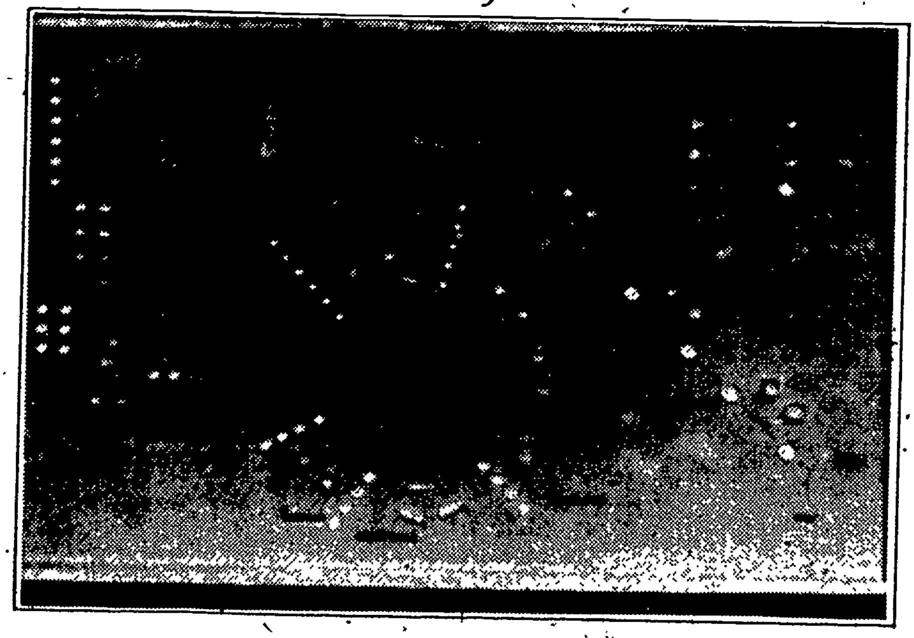


FIG. 15

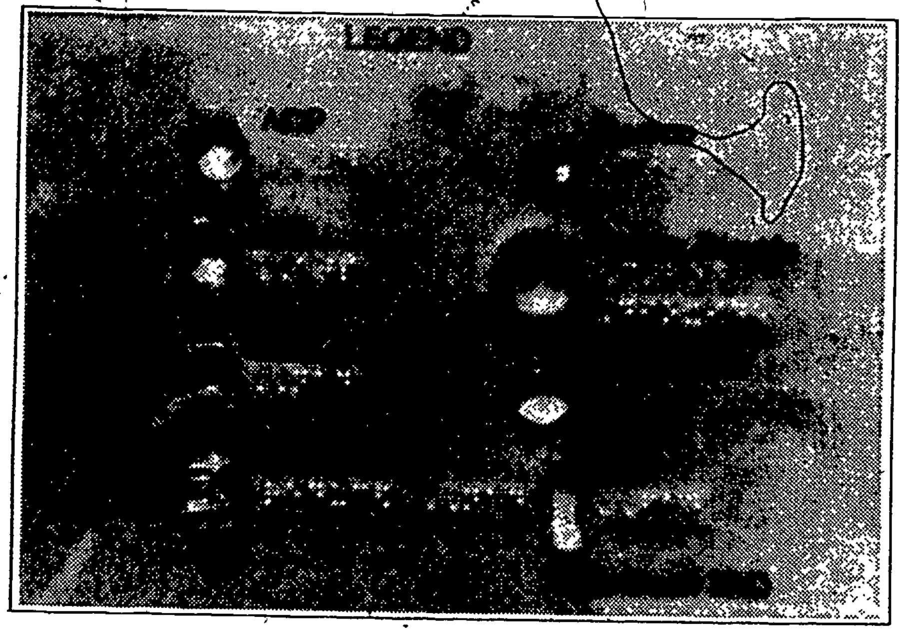


FIG. 16

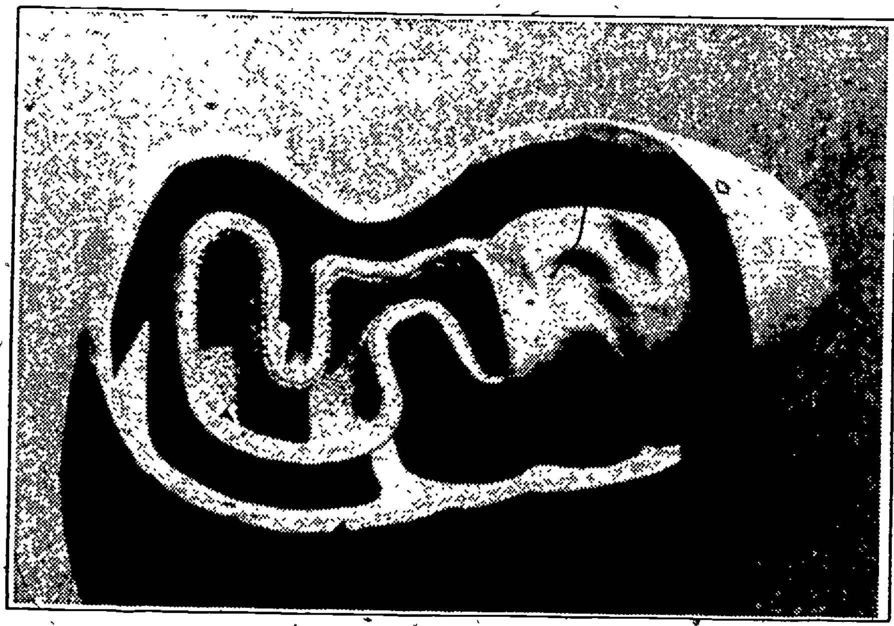


FIG. 17

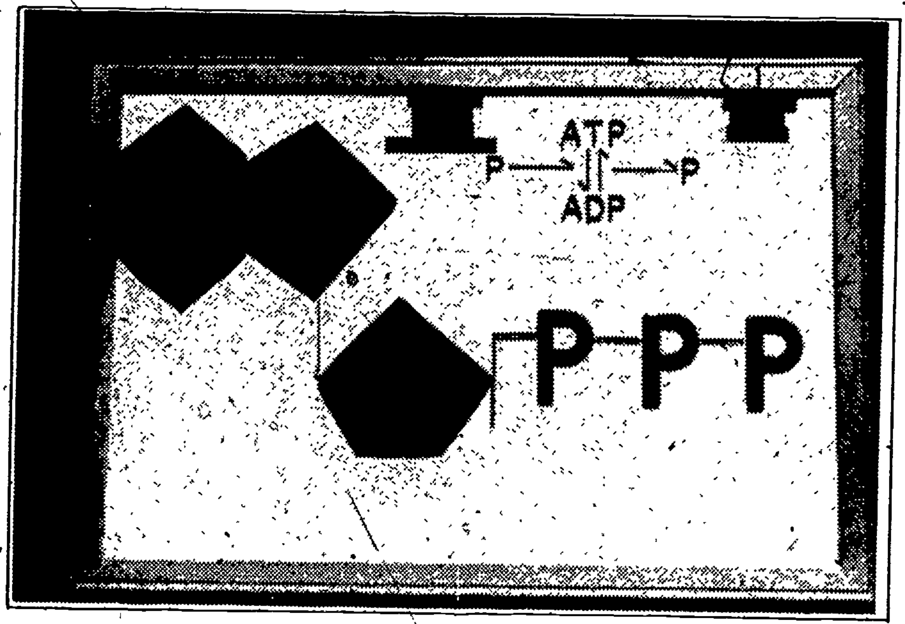


FIG. 18

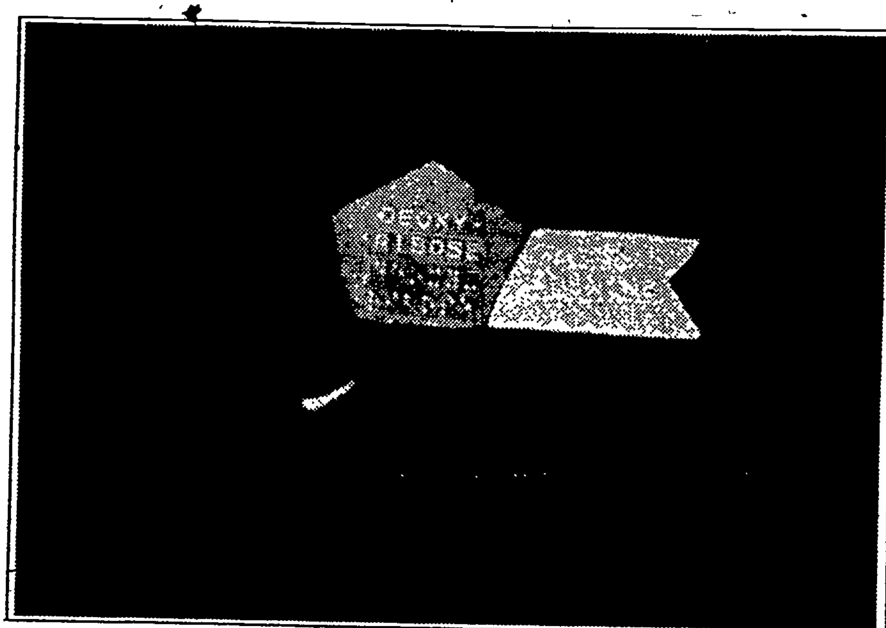


FIG. 19

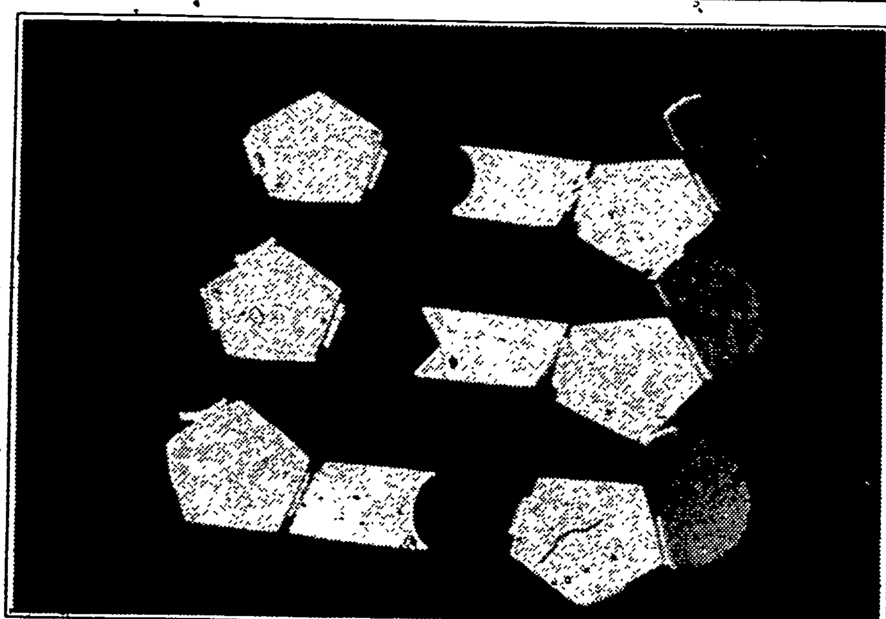


FIG. 20

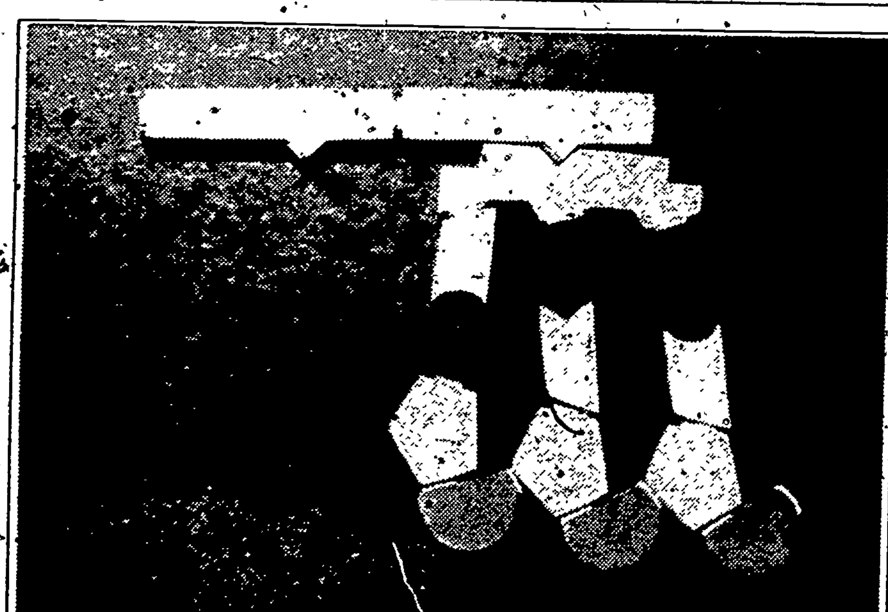


FIG. 21

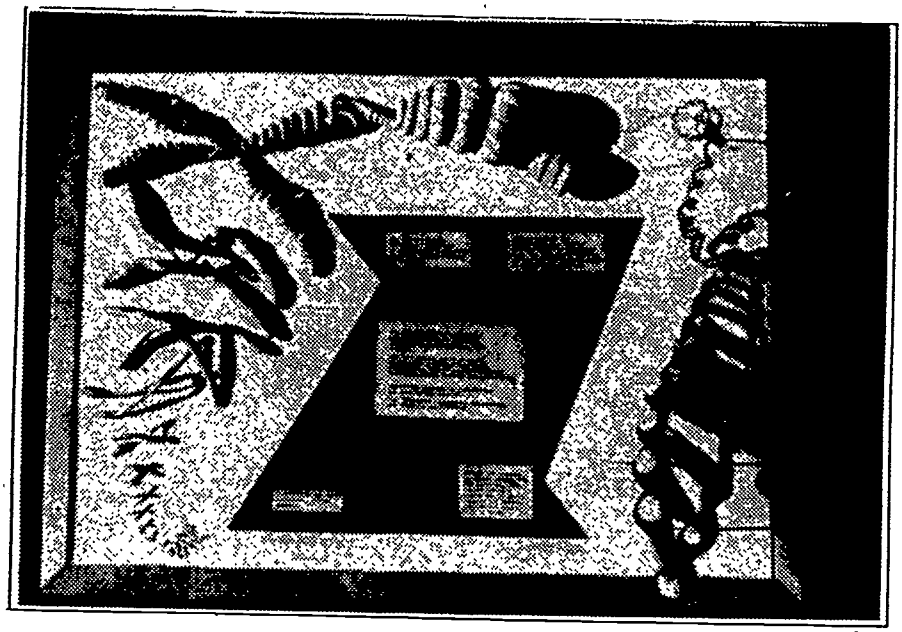


FIG. 22

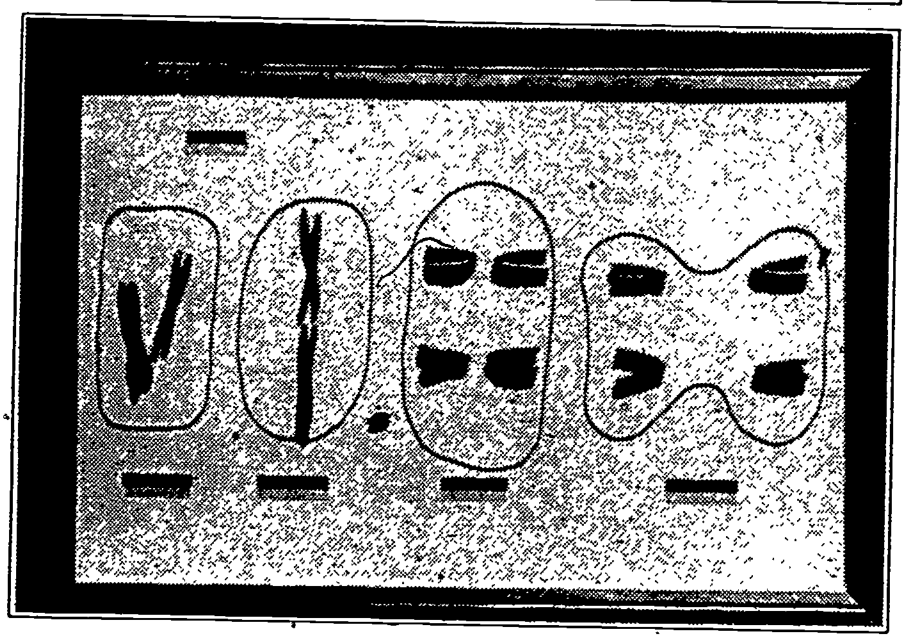


FIG. 23

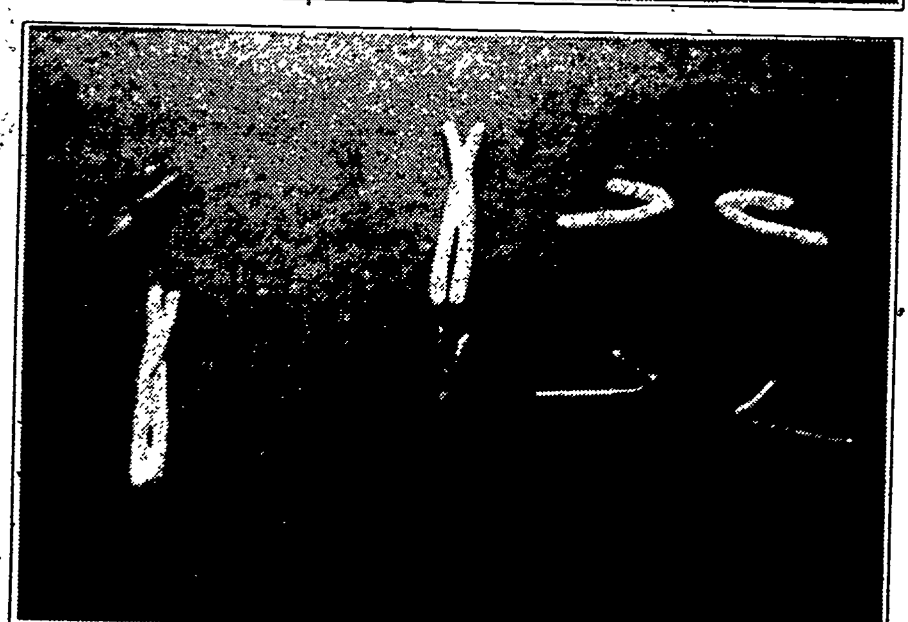


FIG. 24

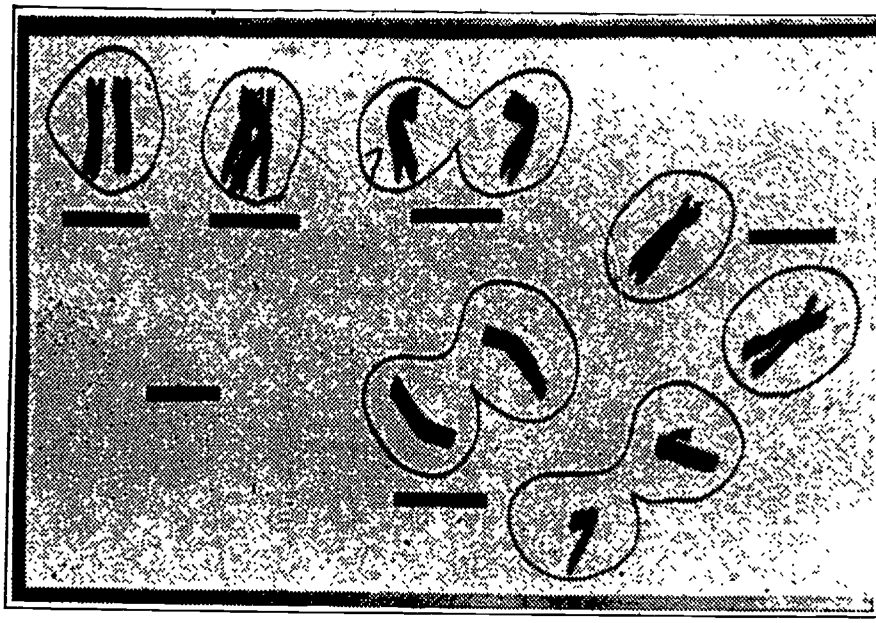


FIG. 25

FIG. 26

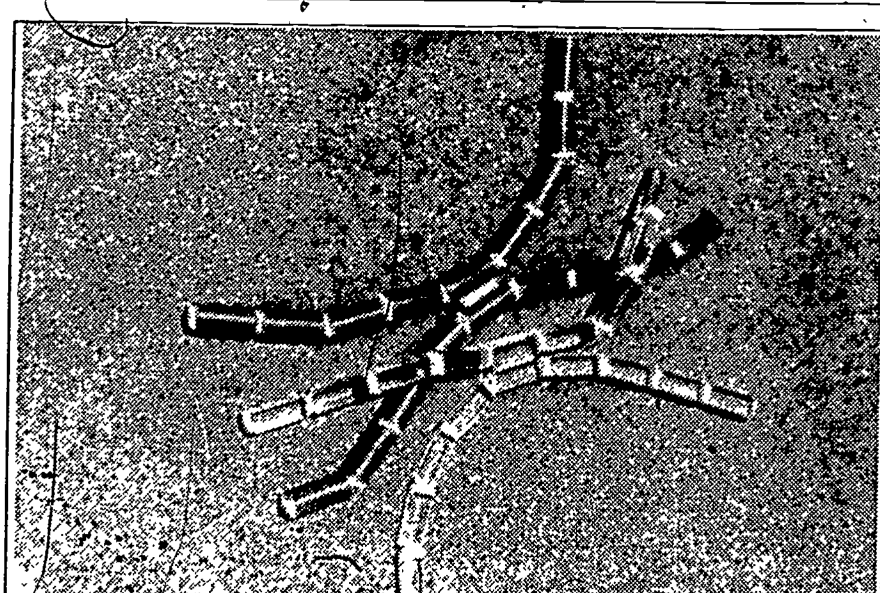


FIG. 27

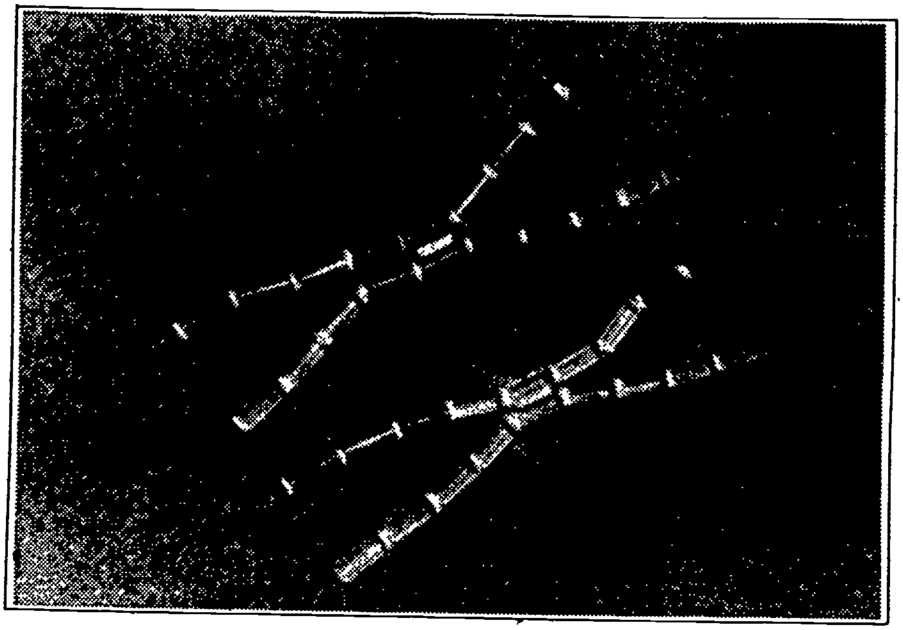


FIG. 28

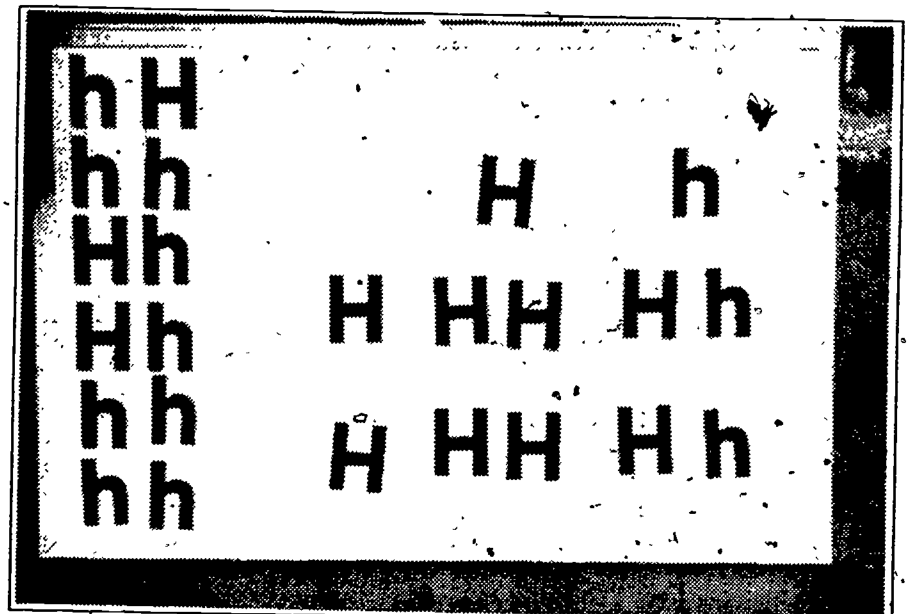


FIG. 29

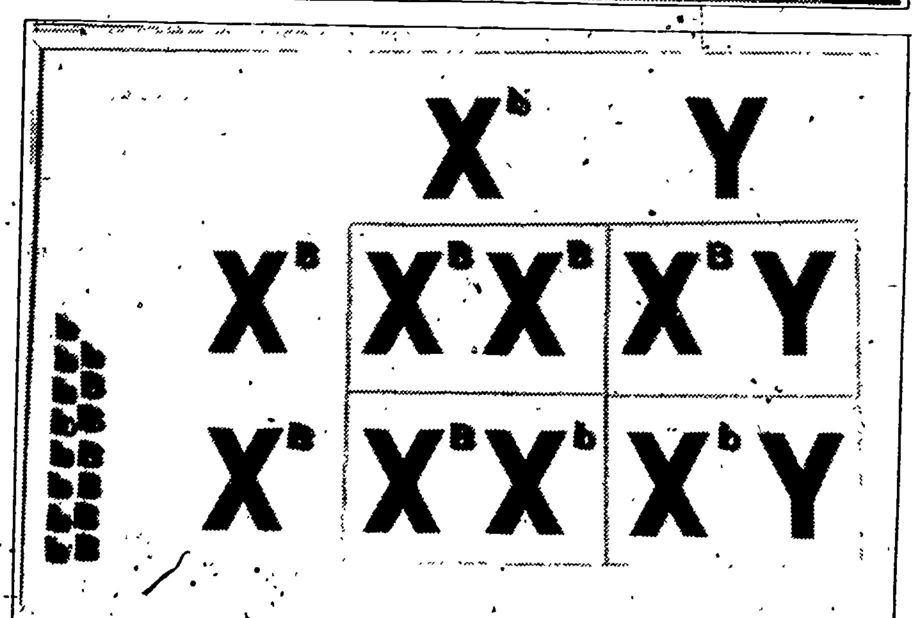


FIG. 30

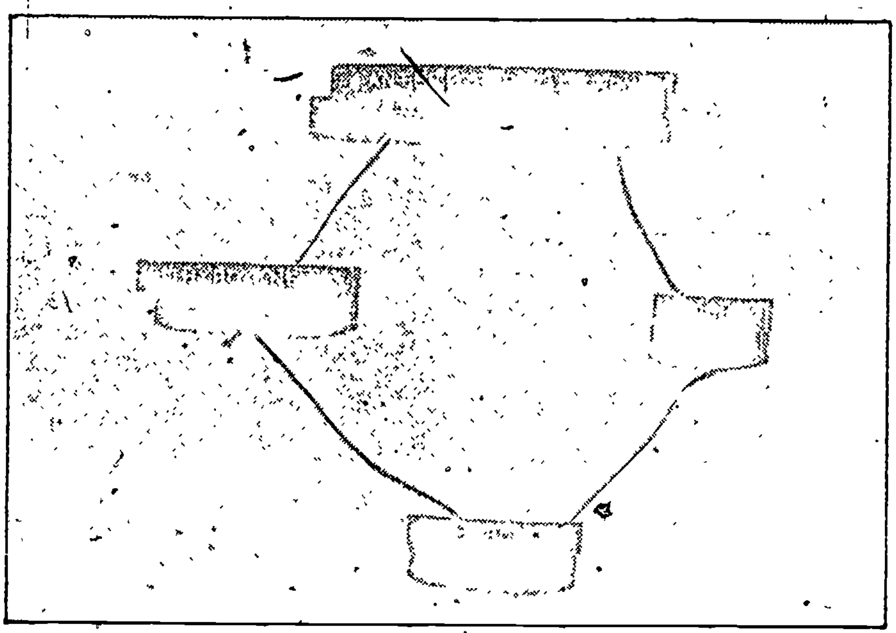


FIG. 31

FIG. 32